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Performance Measurement in Global Product Development

The selection and application of key performance indicators

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The selection and application of key performance indicators

PhD Thesis

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Performance Measurement in Global Product Development

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Abstract

The increased tendency for companies to outsource engineering work or establish captive offshore engineering facilities has resulted in the globalisation of the product development process, which represents a major transformation in industry today. Recent studies highlight how companies adopt a learning-by-doing approach to a form of global product development without a clear understanding towards the key challenges that influence success and as such, decisions are often made on an ad-hoc basis. To support the process of global product development, the need for performance measurement, and in particular the development and application of key performance indicators to enable informed decision making, has been identified from both industrial and academic communities. However, the majority of studies that investigate performance measurement focus on business processes in general and there exists a need to understand performance measurement in the context of global product development.

This thesis describes an investigation to gain an understanding of the challenges manufacturing companies face during the globalisation of the product development process and the current practice for performance measurement in product development projects with globally dispersed engineering teams. The investigation has been conducted in close collaboration with industry, providing access to data, company procedures and possibilities to test methods.

Three empirical studies were carried out with Danish manufacturing companies with offshore research and development facilities in India, China and Poland. Key findings suggest that goal-oriented approaches to performance measurement, typically found in local, cross-functional product development, are not sufficient for global product development given the additional challenges companies face that influence the success of the product development process. The findings also revealed that when managing engineering teams that are globally dispersed, the importance of ensuring clarity and understanding towards the tasks in the product development process itself, rather than simply distributing less complex tasks during global product development projects was highlighted.

From the findings, a method of support was developed that introduces a shift from traditional goal-oriented approaches to performance measurement to include a challenge-oriented approach, which supports the development and documentation of key performance indicators in global product development projects to provide the necessary feedback to develop precautionary strategies that minimise the risk of factors influencing success along the process.

The method has been evaluated and implemented at a Danish manufacturing company and has been used to capture and structure knowledge, which has been utilised in subsequent projects at the company. The research has contributed towards understanding the current practice of performance measurement, in relation to the selection and application of key performance indicators, and developed an in-depth understanding towards the key factors that influence success in global product development.

Abstract (In Danish)

Den stigende tendens til at virksomheder outsourcer forretningsfunktioner til udlandet eller etablerer offshore arbejdspladser har resulteret i en globalisering af produktudviklingsprocessen, hvilket udgør en væsentlig forandring for virksomheder i dag. Nye undersøgelser viser at virksomhederne benytter en learning-by-doing tilgang til global produktudvikling uden at de har en klar forståelse for de særlige udfordringer, der har betydning for succesen, og derfor tages beslutningerne ofte på ad hoc-basis. For at understøtte den globale produktudvikling er der fra både virksomheder og det akademiske miljø udtrykt behov for at få udviklet og anvendt resultatmåling og centrale præstationsindikatorer, der muliggør en informeret beslutningstagning. De fleste undersøgelser, der undersøger resultatmåling, fokuserer imidlertid på forretningsprocesser i almindelighed, og der eksisterer nu et behov for resultatmåling i forbindelse med global produktudvikling.

Denne afhandling beskriver en undersøgelse af de udfordringer, produktionsvirksomheder står overfor, når produktudviklingsprocessen foregår globalt. Den ser også nærmere på den nuværende praksis for resultatmåling i de produktudviklingsprojekter, der har ingeniører spredt over hele verden. Undersøgelsen er gennemført i tæt samarbejde med virksomheder, der har givet adgang til data, procedurer og mulighed for at teste metoder.

Tre empiriske undersøgelser blev gennemført sammen med danske produktionsvirksomheder der har offshore forsknings- og udviklingsfaciliteter i Indien, Kina og Polen. De vigtigste resultater tyder på, at den tilgang til resultatmåling, der typisk findes i lokal, tværgående produktudvikling, ikke er tilstrækkelig til en global produktudvikling på grund af de ekstra udfordringer virksomhederne står over for. Resultaterne viser også, hvor vigtigt det er, når man arbejder med ingeniører fra hele verden, at sikre klarhed og fælles forståelse for selve produktudviklingsprocessen, snarere end blot at fordele mindre komplicerede opgaver.

Baseret på resultaterne af undersøgelsen er der udviklet en metode, der udvikler og støtter et skift fra traditionelle mål-orienterede tilgange til resultatmåling til at omfatte en udfordrings-orienteret tilgang. Denne nye metode støtter udviklingen og dokumentationen af præstationsindikatorer i globale produktudviklingsprojekter og giver desuden den nødvendige feedback der gør det muligt at udvikle forebyggende strategier til at minimere risikofaktorer under processen.

Metoden er blevet evalueret og implementeret af en dansk produktionsvirksomhed og den har været brugt til at indsamle og strukturere viden, som er blevet anvendt i efterfølgende projekter i virksomheden. Forskningen har bidraget til at forstå den nuværende praksis med resultatmåling i forhold til udvælgelse og anvendelse af præstationsindikatorer, og den har udviklet en dybtgående forståelse for de vigtigste faktorer, der påvirker succesen i global produktudvikling.

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Chapter 1 Introduction

This thesis describes an investigation to gain an understanding of the challenges manufacturing companies face during the globalisation of the product development process; and the current practice for performance measurement in product development projects with globally dispersed engineering teams. A method to support project managers with the selection and application of key performance indicators to measure performance of global product development has been developed based upon the findings.

Over the past few decades, advancements with communication technologies have resulted in many western manufacturing companies establishing global production sites in low cost regions such as China or Eastern Europe. More recently, there has been a notable increase in the global dispersion of research and development facilities, particularly in Danish manufacturing companies [Statistics Denmark, 2008], given the opportunity to access new competencies and expertise, be closer to the global market or to reduce development costs. This has a major impact on the practice of product development as companies attempt to manage skilled engineering teams that are globally distributed and culturally diverse to successfully develop products in a collaborative manner. However, companies have been found to adopt a learning-by-doing approach to a form of global product development with ad-hoc decision making along the process, which suggests there is a lack of understanding towards the key challenges that influence success.

To support this process, a need was identified through earlier studies carried out in close collaboration with more than 40 Danish manufacturing companies [Hansen & Ahmed-Kristensen, 2012] to develop an understanding of how performance can be measured in global product development to support decision making along the process.

During this research project, data was collected from Danish manufacturing companies with offshore research and development facilities in foreign locations.

1.1 Motivation for research

The potential of reducing costs by offshoring and outsourcing parts of product development has led to global product development becoming increasingly popular among manufacturing companies, especially within Europe. A recent study involving over 1000 engineering professionals from large manufacturing companies found that 70% of the companies had begun to globalise parts of their product development process to remain competitive in the world market [Eppinger & Chitkara, 2009]. This typically results in the management of globally distributed engineering teams during product development projects and has been referred to in literature as a form of distributed design [Scrivener *et al.*, 2003], collaborative design [Kleinsmann & Valkenburg, 2008] or the internationalisation of product development activities [Cheng *et al.*, 2015]. In this thesis, we refer to this process as global product development.

Global product development represents a major transformation in industry. Understanding the impacts of globalisation on the product development process for both industries and communities is vital.

Recent studies highlight that companies face difficulties during the management of global product development projects, in particular given the increased need for managing culturally diverse and geographically dispersed engineering teams [McDonough, 2001, Anderson & Parker, 2012, Kalyandurg & Akhilesh, 2012]. Furthermore, companies have been observed to adopt a learning-by-doing approach to global product development with decisions being made on an ad-hoc basis, which can be costly later down the process [Hansen & Ahmed-Kristensen, 2011]. To support decision making in GPD, performance measurement and the development of key performance indicators to support the identification and avoidance of problems as they arise has been highlighted [Christodoulou *et al.*, 2007, Hansen & Ahmed-Kristensen, 2012].

Performance measurement, described as a practical tool to support decision making [Kaplan & Norton, 1992], has received much attention in literature over the past few decades and research towards this at the business-level is relatively mature [Kaplan & Norton, 1996, Neely *et al.*, 2000]. However there has been less focus towards performance measurement in the context of global product development at the project-level, which becomes increasingly important given the tendencies of companies to outsource or offshore parts of their product development process [Eppinger & Chitkara, 2009, Hansen & Ahmed-Kristensen, 2012]. As such, there is a need to understand the current practice for performance measurement in global product development at the project-level. Furthermore, the importance of understanding the factors influencing success of a process in such context to support the identification and/or development of “predictive performance measures” was a key area highlighted in literature for future research [Neely *et al.*, 2005].

The learning-by-doing approach to global product development suggests that key challenges that influence the success of global product development projects are not yet fully understood. The majority of studies that investigate the impacts of global product development consist of interviews or observations of short design sessions and focus on specific stages during the product development process [Hansen & Ahmed-Kristensen, 2011, Tripathy & Eppinger, 2011, Eris *et al.*, 2014]. However, there is a need to investigate global product development with longitudinal studies to provide the in-depth insight required to trace problems back to their initial causes and hence, support management in setting up precautionary strategies to better manage global product development projects. The need for such studies is further supported in literature [Huang *et al.*, 2009, Andersson & Pedersen, 2010].

These studies suggest that there is a need to understand performance measurement and the selection and application of key performance indicators in global product development at the project-level to support decision making along the process. In addition, the learning-by-doing approach to global product development suggests that the key challenges that influence the success are not yet fully understood and there is a need to understand this to support the development of precautionary strategies.

1.2 Research aims and questions

The research aims to contribute towards developing an understanding of the current practice for performance measurement in global product development with a focus at the project-level. The specific aims of this research project are:

- To gain an understanding of the current practice for the selection and application of key performance indicators in global product development.
- To develop an understanding of the key factors influencing success in global product development.
- To develop an approach that supports the identification and monitoring of key factors influencing success in global product development projects to support managers in making informed decisions along the process.

To address these aims, research questions were formulated for the different stages of the research project and are presented in the following section and discussed in more detail in Chapter 3 section 3.2.

This thesis is an article based thesis and includes seven papers that were written during the research. The seven papers are presented according to the research questions they address. The seven papers contribute as a whole or as excerpts to the different stages of the research project, which is discussed in more detail in Chapter 3 section 3.2 (refer to Appendix 5 for papers). In addition, a summary of the key findings and contributions from each of the seven papers at the different stages of the research project is presented Appendix 5.

Research question 1	What is the current practice for measuring performance in conventional and global product development projects?
Paper 1	Performance Measurement in Global Product Development
Reference	*Taylor, T. P., Ahmed-Kristensen, S. 2013. "Performance Measurement in Global Product Development." Proceedings of the 19th International Conference on Engineering Design – ICED, 2013, Seoul, South Korea.*
Paper 2	The applicability and coherence of key performance indicators in global product development
Reference	*Taylor, T. P., Ahmed-Kristensen, S. 2014. "The applicability and coherence of key performance indicators in global product development." Proceedings of the 13th International Design Conference – DESIGN, 2014, Dubrovnik, Croatia.*

Research question 2	How are key performance indicators used to monitor factors influencing success in global product development projects?
Paper 3	Key performance indicators: Global product development
Reference	*Taylor, T. P., Ahmed-Kristensen, S. 2014. "Key performance indicators: Global product development." Proceedings of the 21st EurOMA conference: Operations management in an innovation economy, 2014, Palermo, Italy.*
Paper 5	Longitudinal observations of globally distributed design teams: The impacts on Product Development
Reference	*Taylor, T. P., Ahmed-Kristensen, S. 2015. "Longitudinal observations of globally distributed design teams: The impacts on Product Development." Proceedings of the 20th International Conference on Engineering Design, 2015, Milan, Italy.*
Paper 6	Globally distributed design teams: The impacts on product development
Status	*Submitted to the International Journal of Operations & Production Management.*

Research question 3	How to support the selection of key performance indicators that provide project management with timely feedback on performance?
Paper 4	Global product development projects: Measuring performance and monitoring the risks
Status	*Submitted to the journal of Production Planning & Control.*

Research question 4	How does the proposed method support the process of selecting key performance indicators in global product development projects?
Paper 7	Global product development: KPI selection support
Reference	*Taylor, T. P. and Ahmed-Kristensen, S. (2016), "Global product development: KPI selection support" 14th International Design Conference – DESIGN, 2016, Dubrovnik, Croatia.*

This project aims to advance the state of the art and contribute to the field of global product development through developing an in-depth understanding towards the key factors influencing success during the global dispersion of engineering design activities and the current practice for performance measurement to support decision making in Danish manufacturing companies.

1.3 Thesis structure

Figure 1-1 outlines the structure of this thesis and describes each of the chapters in relation to the overall research methodology. The overall research methodology employed is described in Chapter 3 section 3.1. The structure of the thesis is summarised below.

Chapter one, Introduction. This chapter provides the background to the research together with the research aims and questions and discusses the main terms used. The structure of the thesis is also outlined.

Chapter two, Literature Review. This chapter provides the background to the research area and identifies areas for further research. Literature is reviewed in the areas of: (1) conventional product development; (2) global product development; and (3) performance measurement.

Chapter three, Research Approach. This chapter describes the overall research methodology and the research methods employed for each of the studies carried out. The research issues related to carrying out empirical research within industry are also discussed.

Chapter four, <u>Results</u>. This chapter describes the main findings from each of the studies carried out and relates these to the findings from the literature reviewed.

Chapter five, <u>Method of Support and Preliminary Evaluation</u>. This chapter describes a proposed method to support the selection and application of key performance indicators to measure performance in global product development based upon the findings from the research. A preliminary evaluation of the method within a Danish manufacturing company is also discussed.

Chapter six, <u>Conclusions</u>. This chapter presents a summary of the research findings together with the main conclusions. Possible areas for future research are also discussed.

A <u>Glossary</u>. The glossary describes the use of terms in this thesis.

The thesis contains the following Appendices:

<u>Appendix 1</u>, This appendix provides key performance indicators used in conventional product development identified during the literature review of this research.

<u>Appendix 2</u>, This appendix includes the questions asked in the two surveys conducted during the exploratory study of this research.

<u>Appendix 3</u>, This appendix includes the questions asked in the interviews conducted during the multiple case studies of this research. An example of a categorised interview transcript and the structure and categorisation of the field notes taken during the observations is also provided.

<u>Appendix 4</u>, This appendix includes the instructions for the implementation of the support method developed and the questions asked in the interviews and surveys for the evaluation of the support method.

<u>Appendix 5</u>. This appendix includes the seven papers written during this research project. A summary of the key findings and contributions from each of the seven papers is also included.

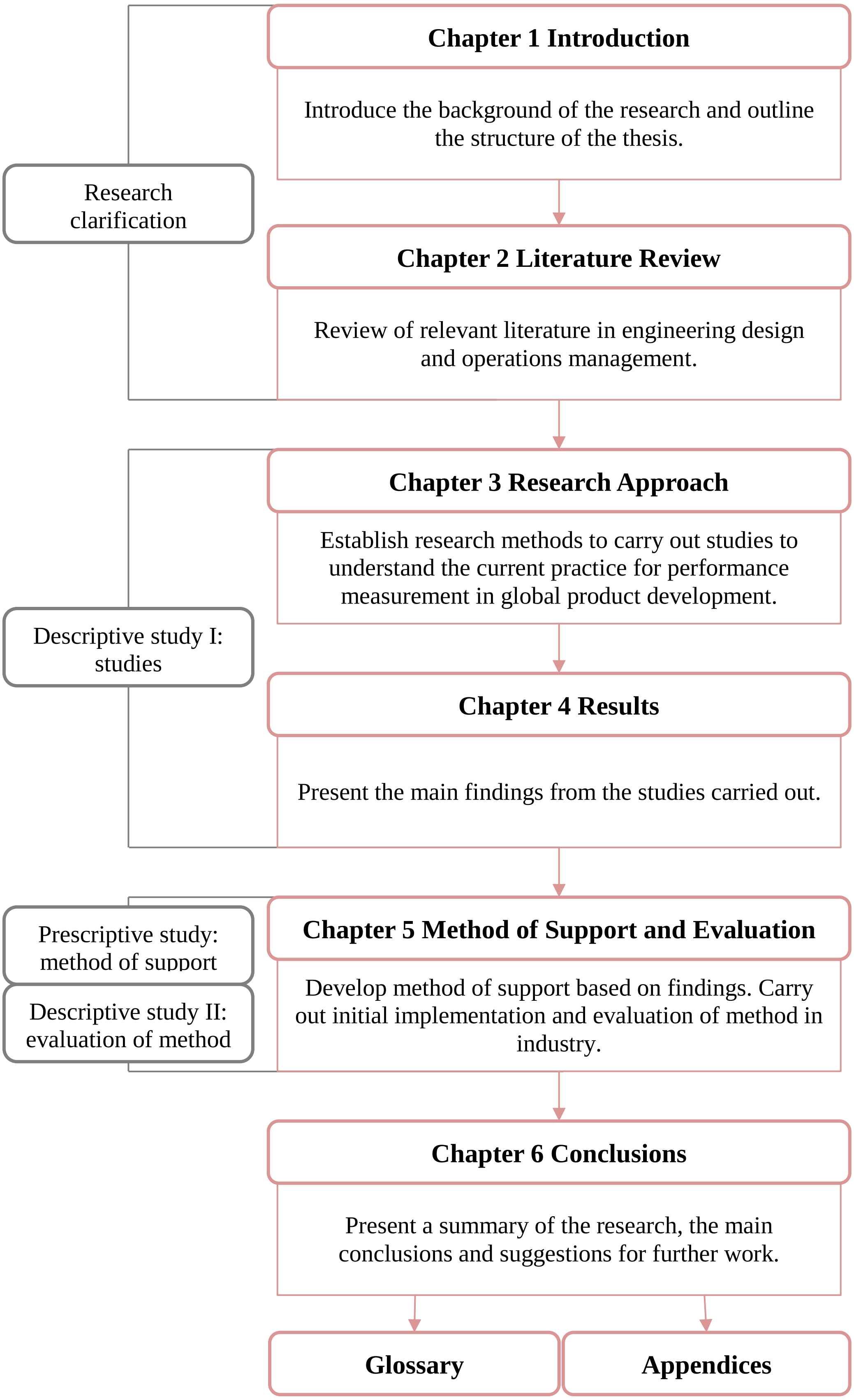

Figure 1-1 Structure of thesis

1.4. Terminology

The globalisation of the product development process occurs when companies *offshore* or *outsource* their business functions (that were previously performed in-house) to overseas locations. Companies either embark on offshoring internally, by setting up their own centres or subsidiaries in foreign countries while maintaining full ownership and control or externally, by handing over business functions to independent foreign providers [Kedia & Mukherjee, 2009]. The companies that participated during the empirical studies in this research project were large Danish manufacturing companies with recently established offshore research and development functions in India, China and Poland.

The globalisation of tasks and activities throughout the product development process (from the early concept development stage and detail design through to the final testing of prototypes before production) is referred to in this thesis as *global product development*. In comparison to conventional product development, which typically consists of local, cross-functional engineering teams, global product development consists of engineering teams that work collaboratively across multiple geographic locations and are culturally diverse [Eppinger & Chitkara, 2009]. The collaboration of geographically dispersed engineering teams during the completion of product development projects is the focus for the investigations reported in this thesis.

Performance measurement has been identified as a practical method to support decision making. Performance is defined as the effectiveness and efficiency of a process with the purpose of achieving a fixed objective or set of goals [Kaplan & Norton, 1992, Neely *et al.*, 2002]. *Performance measurement* requires a set of key performance indicators, which are defined as quantifiable metrics that help an organisation measure the success of critical factors. The process for selecting key performance indicators and their application at the project-level is the focus for the investigations reported in this thesis.

Additional terms have been defined as and when they are used throughout the thesis, and also in the Glossary at the end of the thesis (refer to Glossary).

Chapter 2 Literature Review

In this chapter, the literature is reviewed from three domains identified as relevant for this research, namely: (1) conventional product development; (2) global product development; and (3) performance measurement. The research focuses on performance measurement in global product development at the project-level. To develop an understanding of performance measurement and inform the development of precautionary measures, key factors influencing success in both conventional and global product development need to be identified, hence their inclusion in the review. The review of the performance measurement literature that follows focuses on the selection and use of key performance indicators, which are integral to a successful performance measurement system. The review serves to provide a conceptual basis for the three empirical studies presented in the subsequent chapters.

The review is structured as follows: in conventional product development, the stages manufacturing companies employ to conceive, design and commercialise a product are described; the complexities when defining success are highlighted; and the factors influencing success at the project-level are outlined. Following this, the trend that has seen companies shift from local, cross-functional product development to global product development is described and the additional opportunities and risks this brings are reviewed. Key management approaches to deal with this transformation are presented. Concepts in performance measurement, with a focus on the selection and use of key performance indicators in both conventional product development and global product development, are reviewed and current tools to support this selection are presented. The seven papers written during this research also contain parts of the literature review and are referred to when necessary (refer to Appendix 5 for papers).

2.1 Conventional product development

For a company to conceive, design and commercialise a product, a product development (PD) process comprising a sequence of stages is often employed, from early planning through to final testing and refinement before production ramp up (Figure 2-1). After each stage in the process, a gate must be passed where the previous stage is reviewed before moving to the following stage. The type of PD process employed at the company is largely dependent on the product to be developed [Ulrich & Eppinger, 2011]. In this thesis, the process illustrated in Figure 2-1 for PD is the main reference as this is among the most commonly used in manufacturing companies. Conventional PD typically consists of local, cross-functional members that work collaboratively during the development of products [McDonough *et al.*, 2001, Eppinger & Chitkara, 2009].

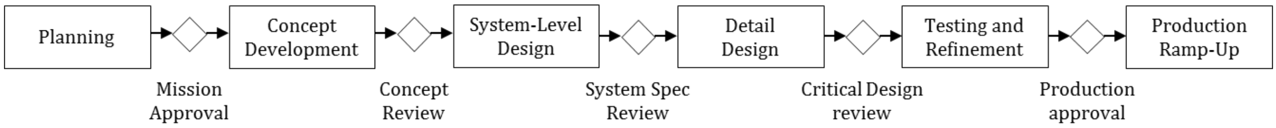

Figure 2-1 The generic product development process [Ulrich & Eppinger, 2011]

2.1.1. Defining PD success

Success in PD projects is multifaceted and difficult to define. Lim and Mohamed [1999] argue that there are two possible viewpoints to success in PD projects: macro-level success and micro-level success. The macro viewpoint is concerned with the eventual operation/ functions or long-term gains of the project; whereas as the micro viewpoint pertains to the traditional Iron Triangle of whether the project is on-time, within budget, and according to specifications. Based on these viewpoints, a company executive will likely have a different perception than a project manager in relation to PD success and hence, the measures of success should be different. Cooper [1998] argues that success at the project-level may be somewhat different to that at a business-level. For example, a string of successful projects, based on a high return-on-investment, may have little impact at a business-level and so the business' total new product effort may be minimal. Furthermore, the type of PD project adds to the multidimensionality of success. Griffin and Page [1996] found that for projects involving radically new innovation, the acceptance of the product from the customer when determining success becomes increasingly important. However, in projects where only incremental changes were made to existing product lines the technical performance of the product was found to be of higher importance.

In the project management literature, the criteria for success have been associated with the traditional Iron Triangle of time, cost and quality [Atkinson, 1999, Hoegl *et al.*, 2004, Toor & Ogunlana, 2010, Gries & Restrepo, 2011]. However, the less tangible nature of outputs from PD activities and the broad range of factors influencing success along the process result in many factors being neglected when determining success in the context of PD when considering the Iron Triangle alone [Toor & Ogunlana, 2010, Snider *et al.*, 2016]. As such, a number of studies propose additional dimensions when determining success in PD projects. For example, Bryde and Brown [2005] propose that the overall satisfaction of stakeholders should be considered when determining success and Belout and Gauvreau [2004] and Wang *et al.*, [2010] introduce the notion of being able to manage PD project risk as an approach to evaluate the success in PD projects.

Success at the project-level in PD is multidimensional and is dependent on the environment in which it operates and the many different stakeholders involved during the process [Hales, 1987]. Difficulties in defining success arise from the long duration and wide range of influences on success and the less tangible nature of outputs from PD activities, such as being knowledge based. Understanding the key factors that influence success in PD projects is a critical step towards developing preventative measures for researchers and practitioners and hence, can support with the management and monitoring of PD projects [Badke-Schaub & Frankenberger, 1999].

2.1.2. The influences on success

Identifying factors that influence success is a topic that has received much attention in the engineering design field. When investigating such factors at the project-level; Hales [1987] and Badke-Schaub and Frankenberger [1999] identified large numbers of factors that were critical for success during the observed engineering design projects. Many studies investigate the impact that factors such as teamwork [Hoegl *et al.,* 2004], shared understanding [Kleinsmann & Valenburg, 2008] or knowledge sharing [Ahmed-Kristensen, 2001] have on success in PD specifically. In this section, the literature is reviewed from a holistic viewpoint in the attempt to provide a comprehensive list of critical factors that contribute to the success of conventional PD at the project-level. The literature search focusses on studies that provide a rich understanding within an industrial setting where possible i.e. observational studies of PD projects (as opposed to studies with students), to understand the cause-effect relationships of identified factors. 14 key articles were identified from journals in engineering design and operations management fields that provided a close fit to the criteria for review, i.e. the studies provided: a rich understanding within an industrial context of the activities carried out during the different stages in the PD process; and identified factors influencing success at the project-level. Based on previous studies investigating similar phenomena [Hales, 1987, Badke-Schaub & Frankenberger, 1999], the key influence factors identified during the review were grouped according to the following influence categories:

- The Individual/ Task – the tasks conducted by the team for the development of the product.
- The Team – the group of design engineers responsible for the development of the product.

- The Process – the sequence of steps employed to conceive, design and commercialise the product.
- The environment – the surroundings in which PD takes place.

The key influence factors identified are presented in Table 2-1 and summarised in the following sections according to their influence categories.

Influence category:	Influence factor:	Example of impact at the project-level:	References:
Task/ Individual	Experience	The availability of information to solve design tasks.	[Badke-Schaub & Frankenberger, 1999, Macmillan *et al.*, 2001, Charnley *et al.*, 2011]
	Individual characteristics	The quality of teamwork in the project team.	[Hoegl *et al.*, 2004, Jerrard *et al.*, 2008, Charnley *et al.*, 2011]
	Commitment	The willingness to perform towards project objectives.	[Hoegl *et al.*, 2004]
	Task complexity	The level of commitment within the project team.	[Hoegl *et al.*, 2004, Van Oorschot *et al.*, 2005, Jerrard *et al.*, 2008]
Team	Team integration	The open exchange of ideas within the project team.	[Hales, 1987, Badke-Schaub & Frankenberger, 1999, Reid, 2000]
	Forming and sustaining partnerships	The access to multiple perspectives and innovation opportunities.	[Charnley *et al.*, 2011]
	Alignment of interests	The amount of design re-works and disputes.	[Macmillan *et al.*, 2001, Charnley *et al.*, 2011]
	Project management	The level of autonomy within the project team.	[Brown & Eisenhardt, 1995]
	Coordination	Team performance and communication channels. .	[Badke-Schaub & Frankenberger, 1999, Hoegl *et al.*, 2004]
	Team competencies	The amount of risk involved toward the completion of the project.	[Hales, 1987, McDermott, 1999]
	Communication	The communication channels; and availability of information in the project team.	[Perry & Sanderson, 1998, Reid, 2000, Chan *et al.*, 2011]
	Senior management	The balance of adequate intervention and oversight within the project team.	[Brown & Eisenhardt, 1995, Crabtree *et al.*, 1997]
	Project team organisation	The availability of information; and communication in the project team.	[Brown & Eisenhardt, 1995, Macmillan *et al.*, 2001]
	Motivation	The level of performance (effectiveness and efficiency) within the project team.	[Hales, 1987]
Process	Availability of	The availability of physical or	[Crabtree *et al.*, 1997, Badke-

	information	electronic information to support knowledge sharing.	Schaub and Frankenberger, 1999]
	Decision making process	The time taken to receive feedback from the project manager.	[Badke-Schaub and Frankenberger, 1999, Jerrard *et al.*, 2008]
	Human and non-human interaction	The frequency of communication and integration of the team.	[Perry & Sanderson, 1998, Charnley *et al.*, 2011]
	Systematic design approach	The level of integration; and alignment of tasks in the project team.	[Hales, 1987, Brown & Eisenhardt, 1995, Reid, 2000]
Environment	Alliances	The accessibility of information external from the project team.	[McDermott, 1999]
	Suppliers	The speed and productivity of the PD project.	[Brown & Eisenhardt, 1995]
	Cultural context	The environment where new products are to be developed.	[Jerrard *et al.*, 2008]

Table 2-1 Key factors influencing success in conventional PD projects

2.1.2.1. The individual/ Task

The complexity and novelty of tasks shapes the environment where PD takes place in terms of its uncertainty or stability and has been associated with project motivation and commitment, which are key moderators for success [Brown & Eisenhardt, 1995, McDermott, 1999, Edmondson & Nembhard, 2009]. For example, in projects where task complexity is high, the level of uncertainty and ambiguity increases and teams look to incorporate knowledge from various functional disciplines, bringing rise to new opportunities and increasing innovation in order to efficiently handle tasks [Hoegl *et al.*, 2004]. Furthermore, the individual characteristics and experience of the team plays an important role. During observations of a PD project [Badke-Schaub & Frankenberger, 1999], all of the successful solution decisions were influenced by the availability of information and communication, of which individual characteristics and experience were the most significant contributing factors.

2.1.2.2. The team

The importance of communication and coordination in PD has been frequently discussed [Reid, 2000, Hoegl *et al.*, 2004]. Badke-Schaub and Frankenberger [1999] observed that informal communication within the team created a “good group climate” and supported team integration, which translated to economic value in terms of time-saved in the project. However and also confirmed by Hoegl *et al*. [2004], McDermott [1999] observed across four projects that when the team attempted to gather information to address the problem in the project, communicating with and involving external parties from the project in the early stages of PD, such as manufacturers, created a hindrance rather than a help and often resulted in confusion. The project manager plays an important role in coordinating such involvement and managing communication both internally and externally from the project team [Krishnan & Ulrich, 2001]. In Brown and Eisenhardt's study [1995], the project leader influenced the organisation of work in the PD team, which in turn impacted the performance and effectiveness of projects. In the most successful projects reported, the senior management only applied subtle controls to the projects, providing team members with the freedom to work autonomously. Furthermore, ensuring the alignment of interests during early stages of PD between the involved parties was critical in avoiding inefficiencies later in the process [McDermott, 1999, Macmillan *et al.*, 2001, Charnley *et al.*, 2011]. The frequency of informal communications and interactions is important to support this alignment.

2.1.2.3. The process

During a longitudinal study of an engineering design project, Hales [1987] found that a clear understanding toward the systematic design approach, such as the process illustrated in Figure 2-1, increased motivation within the project team and supported the prioritisation and coordination of tasks. The decision making process in PD projects has frequently been described as a key cause for project time delays and is dependent on factors within each of the influence categories in Table 2-1. Badke-Schaub and Frankenberger [1999], Jerrard *et al*. [2008] and Hoegl *et al.* [2004] all found that a slow decision making process was a consequence of low availability of information at the company, the organisation of the project team and the role played by the project manager.

2.1.2.4. The environment

Considering the environment where PD projects take place, Hales [1987] identified a set of "slow changing" influences such as corporate organisation and "continuously changing" influences such as motivation and commitment. The impact that the "slow changing" influences have on PD success in comparison to "continuously changing" is difficult to measure from single observations of development projects due to the amount of time required to observe the change. This goes some way to explaining the limited number of studies identified at this level of influence. However, Jerrard *et al*. [2008] state that “The cultural, geographical and historical contexts (where PD takes place) are important and shapes the organisation and the development of new products”.

Summary

Grouping the identified key influence factors according to the different influence categories supports to clarify and compare factors across studies. The factors identified act as both positive and negative mechanisms that influence success in conventional PD projects. A key moderator, which appears central to the success, is the availability of information, which is influenced by individual characteristics, communication and an understanding towards the systematic design approach within the PD team. The centrality of this factor can be expected, given the process of conceiving an idea through to the commercialisation of a product has been described as an information processing system [Clark & Fujimoto, 1991, Brown & Eisenhardt, 1995]. Furthermore, the project manager plays an important role in coordinating tasks during PD and ensuring the alignment of interests within the team, particularly during the early stages of PD.

The factors listed in Table 2-1 are highly inter-related across the different levels of influence and the large number of factors indicates the complexity of this topic, which is further elaborated on in paper V and VI. Identifying factors influencing success supports management to develop precautionary measures to better manage PD projects [Badke-Schaub & Frankenberger, 1999, Scrivener *et al.,* 2003]. However, advancements in communication technologies has altered the environment where PD takes place and opportunities to reduce costs, shorten development time or access new resources has resulted in companies globally distributing parts of their PD process. The impact this transformation has on PD projects is discussed in the following section.

2.2 Global product development

Global product development (GPD) is the globalisation of tasks and activities throughout the PD process, from the early concept development stage and detail design through to the final testing of prototypes ready for production (see Figure 2-1 for stages of the PD process). In comparison to conventional PD, which typically consists of local, cross-functional members, GPD consists of teams that work collaboratively across multiple geographic locations that are culturally diverse [McDonough *et al.*, 1999, McDonough *et al.*, 2001, Eppinger & Chitkara, 2009]. This practice may include outsourced engineering work along with captive offshore engineering facilities [Eppinger & Chitkara, 2009, Hansen & Ahmed-Kristensen, 2012]. In this thesis, the following definitions are used for these terms [Hansen & Ahmed-Kristensen, 2012]:

- Outsourcing: moving a task or function to a facility owned by a third party, often to a local company in a low cost country e.g. China, India.
- Offshoring: moving a task or a function to a facility owned by the company to a low cost country e.g. China, India.

Studies have shown that manufacturing companies begin with globalising the production process, with PD activities following. During the global distribution of the PD process, low value adding activities, such as routine design tasks in the later stages of the PD process, are mainly outsourced and higher value adding activities, such as concept development, are mainly offshored [Hansen & Ahmed-Kristensen, 2011]. A key explanation for this relates to the importance of protecting the core competencies of a company.

The migration from conventional PD to GPD represents a major transformation in industry as companies strive to effectively manage engineering teams that are culturally diverse and geographically dispersed [Eppinger & Chitkara, 2009]. Understanding key aspects of culture is important to analyse the impact that cultural diversity may have on GPD.

2.2.1. Cultural diversity

Culture has been described as a dynamic phenomenon that is continuously evolving and is created by interactions with others and shaped by leadership behaviour, and a set of structures, routines, rules, and norms that guide and constrain behaviour [Schein, 2004]. There are different aspects of culture such as professional, ethical, religious, national, group, and organisational culture. Based on previous studies investigating similar phenomenon [Hansen *et al.*, 2011], the following aspects are considered most relevant for this research project: national; group; and organisational culture.

Group culture, which organisational culture falls under, is defined as: “a pattern of shared basic assumptions that the group learned as it solved its problems of external adaptation and internal integration, that has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way you perceive, think, and feel in relation to those problems” [Schein 2004]. When defining national culture, Hofstede [2010] developed five cultural dimensions that represent independent preferences for one state of affairs over another that distinguish countries (rather than individuals) from each other. The five cultural dimensions were developed based on a study conducted from 1967 – 1973 that investigated how values in the workplace are influenced by national culture.

The five cultural dimensions for Denmark, India, China and Poland are illustrated in Figure 2-2 and are used as examples to illustrate the different parameters within the dimensions.

1. Power distance (PDI): Is the extent to which the less powerful members of institutions and organisations within a country expect and accept that power is distributed unequally. In other words, both leaders and subordinates endorse inequality. India, China and Poland are countries with a high PDI. Denmark is at the low end of this dimension compared to other countries. With a very egalitarian mind-set the Danes believe in independency, equal rights, accessible superiors and that management facilitates and empowers.
2. Individualism (IDV): Is the degree of independence a society maintains among its members. In Individualist societies people are supposed to look after themselves and their direct family only. In Collectivist societies people belong ‘in groups’ that take care of them in exchange for loyalty. Denmark is an example of an individualist society.
3. Masculinity (MAS): A masculine society is driven by competition, achievement and success, with success being defined by the winner / best in field – a value system that starts in school and continues throughout organisational life. A feminine society means that the dominant values in society are caring for others and quality of life and standing out from the crowd is not admirable. Denmark is an example of a feminine society and India, China and Poland more masculine.

4. Uncertainty avoidance (UAI): The extent to which the members of a culture feel threatened by ambiguous or unknown situations is reflected in the score on UAI. Poland score highly on this dimension and thus has a high preference to avoiding uncertainty.
5. Long Term Orientation (LTO): Relates to how every society maintains links with its own past while dealing with the challenges of the present and future. Values associated with Long Term Orientation are thrift and perseverance in achieving results; and values associated with Short Term Orientation are high levels of curiosity and a low need for predictability in working life. China scores highly on this dimension, which means that is a pragmatic culture and people tend to believe that truth depends very much on situation, context and time.

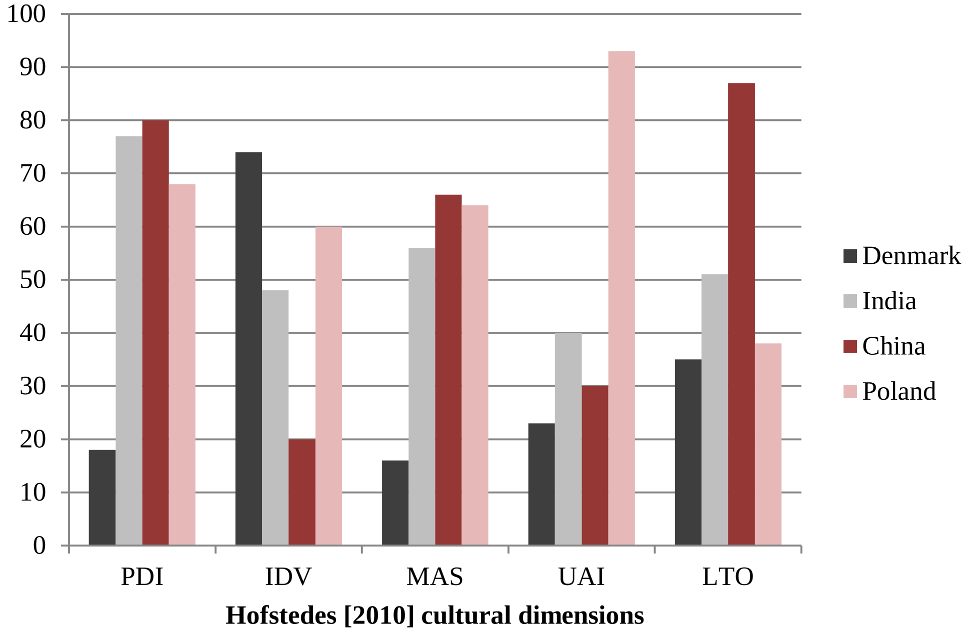

Figure 2-2 Denmark, India, China and Poland according to Hostede’s [2010] six cultural dimensions

The cultural dimensions are a useful tool for comparing the differences of national culture between countries. The dimensions have been adopted in previous studies that investigate cultural differences in outsourcing [Chen *et al.,* 2010] and as such, the dimensions are considered useful for this research project.

2.2.2. The motivations and challenges

Research towards the motivations for GPD in manufacturing companies is beginning to mature. Table 2-2 illustrates motivations from several independent studies in literature, which are the results from case studies and surveys from the manufacturing industry. Reducing costs, by gaining access to low-cost labour and materials in regions such as Asia and Eastern Europe, is frequently referred to in literature as a key motivation for pursuing GPD. However, studies found that companies pursue GPD for reasons other than those directly related to cost reductions and less tangible benefits may include greater engineering efficiency (due to lower-cost resources), increased access to technical expertise distributed globally, the development of products for global markets, increased flexibility in operations or the mitigation of PD risk [Littler *et al.*, 1995, Eppinger & Chitkara, 2009, Verdecho, 2009].

The motivations represent the desirable outcome as a result of pursuing GPD and hence, are important dimensions when evaluating the performance of GPD. For example, if the key motivation was to reduce costs, an important indicator of this could be: cost of local engineers vs cost of global engineers.

Although the motivations are relatively high-level, the importance of aligning business strategy with measures of performance is important and is discussed in more detail in section 2.3.

Motivations	**Example**	**Source**
Cost reductions	Access to low labour costs and materials in low cost regions.	[Christodoulou *et al.,* 2007, Statistics Denmark, 2008, Taylor & Ahmed-Kristensen, 2013]
Access to new resources	Increased access to global competencies and engineering expertise.	[Christodoulou *et al.,* 2007, Hansen *et al.,* 2011, Taylor & Ahmed-Kristensen, 2013]
Increase customer base	Design resources closer to local markets, providing increased knowledge of customer needs.	[Statistics Denmark, 2008, Hansen *et al.,* 2011, Taylor & Ahmed-Kristensen, 2013]
Flexibility and scalability	Transferability of tasks and opportunity to work around the clock.	[Eppinger & Chitkara, 2009]
Reduce time to market	Close to local suppliers and global markets.	[Christodoulou *et al.,* 2007, Statistics Denmark, 2008, Hansen & Ahmed-Kristensen, 2012]
Risk mitigation	Sharing risk during development of new products with global partners.	[Christodoulou *et al.,* 2007, Hansen & Ahmed-Kristensen, 2012]

Table 2-2 Key motivations for GPD from several sources in literature.

Much of the literature has focussed on the challenges involved with GPD, in particular the difficulties with managing globally distributed teams. While physical proximity can reinforce social similarity, shared values and expectations, distance between team members can lead to significant declines in communication and interaction. It is established in literature that coordinating tasks and activities in such environment is challenging [Eppinger & Chitkara, 2009, Hansen & Ahmed-Kristensen, 2011]. Table 2-3 illustrates some of the most frequently discussed challenges for GPD in literature. It can be argued that many of these challenges are also present in conventional PD (see Table 2-1), however, shifting the environment from local, cross-functional PD to GPD has been found to accentuate these factors [McDonough *et al.,* 2001, Scrivener *et al.*, 2003, Sosa *et al.,* 2004, Hansen & Ahmed-Kristensen, 2011, Anderson & Parker, 2012, Kalyandurg & Akhilesh, 2012]. For example, in an environment where distance between teams is increased and frequent, spontaneous interactions are reduced; Hansen and Ahmed-Kristensen [2011] and Kalyandurg and Akhilesh [2012] found in several case studies that complex development tasks became more difficult to manage and resulted in design re-work in the GPD projects observed. Furthermore, a lack of face-to-face interaction between culturally diverse members makes for a challenging environment when identifying and managing conflicts and creating a common vision within globally distributed teams. Frequent and spontaneous interactions have been found to support shared understanding in conventional PD [McDonough, 2001, Kleinsmann & Valkenburg, 2008] and the need for communication quickly, richly and with high volumes of information to support shared understanding increases in GPD [McDonough *et al.*, 1999]. Given this, the time required for project managers to coordinate such projects increases and the maintenance of the collaborations may become the prime objective rather than the development of the product itself [Littler *et al.*, 1995]. Crabtree *et al.* [1997] found that activities involving coordination in GPD projects occupied 69% of an engineer's time. McDonough *et al.* [1999] and Kalyandurg and Akhilesh [2012] found that an increased workload for project management in GPD negatively impacted the speed of the decision making process, which in turn led to frustration with global partners and resulted in time delays and design rework.

Similar to Table 2-1, the challenges in Table 2-3 represent key factors that influence the success of GPD and hence, are important factors to consider when ensuring the achievement towards the desirable outcome for GPD. For example, if the key motivation was to reduce costs, the financial impact that standardising tools and processes or ensuring transparency with company documentation are important factors to consider [Hansen & Ahmed-Kristensen, 2011]. The notion of managing risk as an approach for evaluating success in conventional PD has been discussed [Wang *et al.*, 2011]. However, shifting from local, cross-functional PD to GPD has been found to accentuate the factors influencing success and as such, monitoring such factors when evaluating performance in GPD becomes increasingly important.

The majority of studies that identify the key challenges for GPD (Table 2-3) consist of interviews or observations of short design sessions and do not provide the in-depth insight required to investigate the impact that such challenges may have on GPD at the project-level. Developing this understanding is an important step to support management in setting preventative measures to avoid the impacts on success.

Challenges	Example	Source
Cultural differences	Contrasting levels of autonomy in project team due to cultural background.	[Tomico, 2009, Hansen & Ahmed-Kristensen, 2011]
Communication	Conflicting communication styles: high context and low context.	[Hansen & Ahmed-Kristensen, 2011]
Documentation	Transfer of company documentation to digital platform accessible to global partners.	[Crabtree *et al.*, 1997, Barthelemy, 2003]
Lack of common vision	Strategic vision created locally at headquarters rather than with global partners.	[Hansen & Ahmed-Kristensen, 2012, Cash & Ahmed-kristensen, 2015]
Intellectual property rights	Ideas and inventions can be compromised when shared with parties outside of the company.	[BusinessWeek Research Services, 2006]
Knowledge sharing	Transferring local, tacit knowledge to global partners.	[Carmel *et al.*, 2009, Hansen *et al*. 2011]
Standardising tools and processes	Clarity of company processes in common language accessible to global partners.	[Tripathy & Eppinger, 2011, Hansen & Ahmed-Kristensen, 2011]

Table 2-3 Key challenges in GPD from several sources in literature.

2.2.3. A learning-by-doing approach

Despite the difficulties, companies have been found to adopt a learning-by-doing approach to GPD with solutions to the challenges being implemented on an ad-hoc basis. According to Repenning [2001], productivity often fails initially in GPD but recovers in a ‘worse-before-better’ scenario. Hansen and Ahmed-Kristensen [2012] found that companies only considered the positive impacts of moving abroad, leaving few processes in place to handle difficulties. Solutions to these difficulties were implemented on an ‘as needed’ basis and resulted in design rework and project time delays. In addition, the case companies were observed to switch strategies of offshoring and outsourcing. Barthelemy [2003] highlights the need to understand the hidden costs involved with outsourcing. The hidden costs impact the success of GPD and challenge the decision rationale. Barthelemy [2003] concludes that while carefully selecting the vendor and aligning expectations and clearly defining a set of performance measures may be costly, such expenses are necessary to reduce the impact of the hidden costs.

2.2.4. Managing the impacts

When collaborating with globally distributed teams, the reliance on a fully digitalised PD process is increased to support the coordination and alignment of tasks and activities [Eppinger & Chitkara, 2009]. Furthermore, a trend has seen companies attempting to decompose this process into globally distributed work packages, with clear interfaces between packages, to enable distributed teams to work autonomously and alleviate the need for overt managerial authority when coordinating such tasks [Eppinger *et al.*, 2009, Johnsen, 2011, Hansen & Ahmed-Kristensen, 2012]. To successfully deploy GPD at a strategic level in a company, Eppinger and Chitkara [2009] recommends ten key success factors. These are:

1. Priority of management toward global collaborations
2. Process modularity to allow for work package segregation
3. Product modularity to ensure interfaces are clearly defined
4. Identification of core competence to the company
5. Protection of intellectual property
6. Data quality through the use of a single system
7. Infrastructure unification
8. Governance and project management to ensure alignment and execution
9. Collaborative culture
10. Organisation change management to make global product development operational.

Building on these factors, Hansen and Ahmed-Kristensen [2012] developed the Global Decision Making framework in order to further avoid the challenges companies face in GPD (Figure 2-3). The process consists of five stages, which aim to support the implementation of GPD as a corporate strategy. Central to operationalising this framework is the development, implementation and evaluation of key performance indicators that provide continuous feedback to management and hence, support decision making in GPD. The inclusion of such indicators that support the identification of deviations early in the process is further supported in literature to better manage GPD projects [Cánez *et al.*, 2000, Christodoulou *et al.*, 2007].

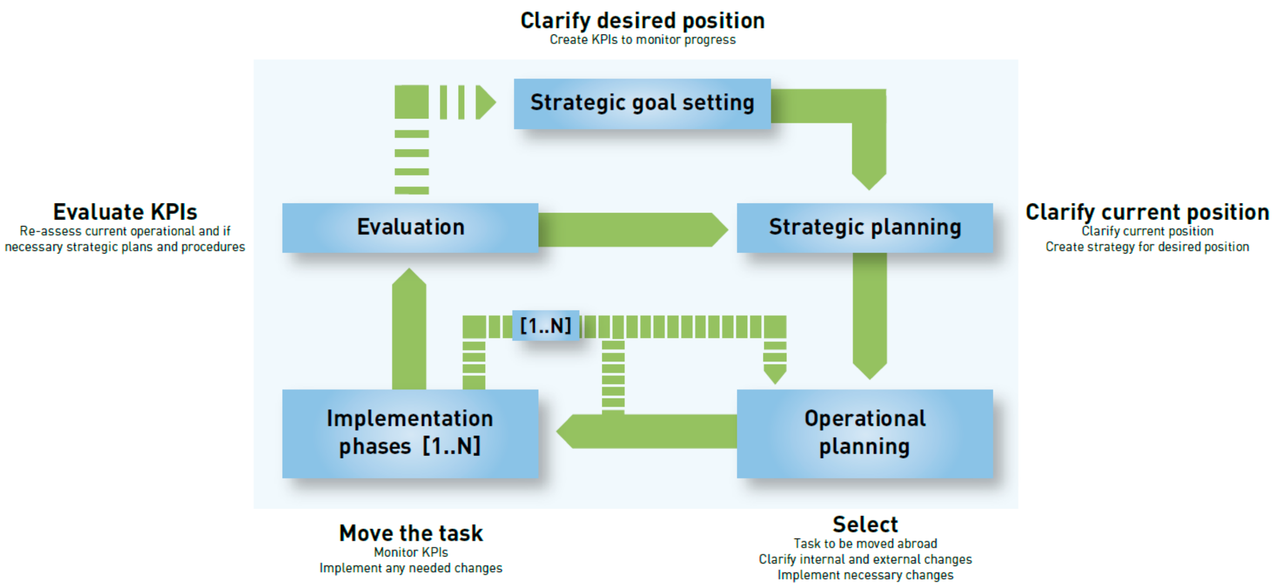

Figure 2-3 The Global Decision Making Framework [Hansen & Ahmed-Kristensen, 2012].

The studies by Eppinger and Chitkara [2009] and Hansen and Ahmed-Kristensen [2012] represent examples of how companies can overcome the challenges faced by companies deploying GPD as a corporate practice. However, in general there is a lack of research toward the development of practical tools in GPD at the project-level [Scrivener *et al.*, 2003, Eppinger & Chitkara, 2009, Anderson & Parker, 2012]. The learning-by-doing approach to GPD suggests that manufacturing companies are yet to fully understand the challenges that influence the success along the process. There are many studies that identify the key challenges in GPD (as illustrated in section 2.2.2), however, the majority of these studies typically consist of interviews or observations of short design sessions and focus on specific stages during the PD process [Hansen & Ahmed-Kristensen, 2011, Tripathy & Eppinger, 2011, Eris *et al.*, 2014]. However, the need to investigate GPD with longitudinal studies to provide the in-depth insight required to trace problems back to their initial causes and hence, support management in setting up precautionary strategies to better manage GPD projects has been highlighted [Huang *et al.*, 2009, Andersson & Pedersen, 2010]. Furthermore, Cánez *et al.* [2000], Christodoulou *et al.* [2007] and Hansen and Ahmed-Kristensen [2012] highlight the importance of including metrics to monitor the factors influencing success in GPD and hence, provide managers with the necessary feedback to make informed decisions and adjustments along the process. This supports managers in making informed decisions, rather than those made on an ad-hoc basis.

Summary

The key motivations and challenges identified are important dimensions to be considered when evaluating the success of GPD. The key motivations represent the desirable outcome for pursing GPD. The key challenges represent the key factors that influence success towards this outcome. Understanding the impact that the key challenges have at the project-level in GPD is an important step towards developing precautionary measures and hence, avoids the learning-by-doing approach to managing GPD projects that has previously been observed in several industrial case studies [Barthelemy, 2003, Hansen & Ahmed-Kristensen, 2011]. The need for developing KPIs to support the identification and avoidance of problems as they arise and hence, support decision making in GPD has been highlighted [Christodoulou *et al.,* 2007, Hansen & Ahmed-Kristensen, 2012], and is further elaborated on in paper II and IV.

2.3 Performance measurement

Performance measurement is an established practical method used to provide accurate feedback on the performance of a process and support decision making [Neely *et al.*, 2000, O'Donnell & Duffy, 2002, Nenadál, 2008]. Performance is defined as the effectiveness and efficiency of a process with the purpose of achieving a fixed objective or set of goals [Kaplan & Norton, 1992, Neely *et al.*, 2002]. The measurement of performance requires a balanced set of financial and non-financial key performance indicators, which are derived from business-level strategy [Neely *et al.*, 2000, Ford & Sterman, 2003]. Performance is measured at different levels within a company, such as the business-level, the project-level or the task-level. At the different levels, employees have access to different information, which require different key performance indicators to guide decisions under their purview [Tatikonda, 2007]. For example, a CEO may be interested in reducing time to market to achieve competitive success. This is also within the interests of project-level managers; however they must also manage and coordinate day-to-day operations within the project team to achieve lead-time reductions. The project team member, who reports to the project-level manager, also shares these concerns; however they will typically only have control over work directly assigned to them and the team (see Table 2-4 for an example). In this thesis, the focus is on performance measurement at the project-level, where less has been reported in comparison to the business-level and is discussed in the following sections.

Organisational level (Position)	Measure of interest
Business unit level (CEO)	Reduce time to market
Project level (Project manager)	Project lead time (time from formal project approval to first customer shipment)
Task level (Project team member)	Number of design engineering drawings redrawn

Table 2-4 Example of performance measurement at different organisational levels [Tatikonda, 2007].

2.3.1. Key performance indicators

Key performance indicators (KPIs) are defined as quantifiable metrics that help an organisation measure the success of critical factors [Gries & Restrepo, 2011]. Kaplan and Norton [1996] state that KPIs can be classified within two categories:

- Leading indicators: that measure factors impacting a process and are drivers of performance.
- Lagging indicators: that measure output of past activity and typically consist of financial indicators.

The two types of indicators are inter-related and the relationship between the two must be understood. Lagging indicators (outcome measures) without leading indicators (performance drivers) do not communicate how the outcomes of a process are to be achieved. For example, Kaplan and Norton [1996] describe the indicators selected by Metro bank where the company's high level strategy was to achieve revenue growth. To achieve this, one of the strategic objectives was to create innovative products. The lagging indicator they selected to measure the outcome of this objective was the 'Amount of revenue from new products'. The leading indicator they selected to drive performance towards achieving this objective was to monitor the 'Amount of hours spent with the customer'. In this case, the leading indicator was driving performance towards creating innovative products by spending time with the customer, whereas the lagging indicator was measuring the financial implications at the end of the process.

During their development of a guide for the implementation, analysis, and interpretation of leading indicators, Rhodes *et al.,* [2009] state that "contrary to simple status oriented measures typically used on most projects, leading indicators are intended to provide insight into the probable future state, allowing projects to improve the management and performance of complex programs before problems arise". Despite this, the development of leading indicators for predictive purposes in systems engineering was found to be an illusive practice, with the majority of performance measures used providing lagging information. Rhodes *et al.,* [2009] explain that although this is useful in showing history and progress of an organisation's efforts, lagging indicators fail to provide information for predictive purposes within the context of a given program, and hence do not allow management to take action before problems arise.

Similarly to Kaplan and Norton [1996] and Rhodes *et al.*, [2009], Fitzgerald *et al.* [1991] developed the Results and Determinants Framework and Parmenter [2012] classifies indicators within Past, Current and Future indicators.

The studies highlight the importance of understanding the factors that influence success of a process when selecting KPIs, rather than those that solely focus on the outcome, and is further supported for performance measurement in product development [O'Donnell & Duffy, 2005]. Such understanding informs the development of leading KPIs that provide the predictive insight to allow management to take action before problems are realised [Rhodes *et al.*, 2009].

2.3.2. You get what you measure

Although KPIs change depending on the different interests at the various organisational levels they are to be used (see Table 2-4), a fundamental rule when developing KPIs is that they are derived from business-level strategy [Kaplan & Norton, 1996, Neely *et al.*, 2000, Ford & Sterman, 2003]. Failure to do so may result in behavioural misalignment at the company, which can have adverse effects on performance. Neely *et al.* [1997] and Parmenter [2012] provide several examples of such misalignment in relation to the manufacturing environment. In PD, Tatikonda [2007] states that a performance measure plays three simultaneous roles, namely:

- The objectives - the disaggregation or statement of a strategy or a plan
- The metrics - the agreed-upon way to measure the managerial construct of interest
- The rewards - the role of distributing benefits to the individuals involved.

The three roles are highly interrelated. For example, the objective presents a direction to work towards, and a challenge to organisational personnel. The reward is incenting (or punishing) and indicates accoutability of development personnel. The metric reflects the desire and ability to collect information to monitor development progress and outcomes. Tatikonda [2007] argues that an organisation that does not recognise the linkages is likely to have disconnected or incongruent objectives, metrics and rewards where each is developed and stated in isolation.

Ensuring KPIs are clearly defined and linked to the business-level strategy is important to avoid behavioural misalignemnt. To ensure clarity when developing KPIs, Neely *et al.* [1997] propose ten criteria which seek to specify what constitute the "good" KPI (Table 2-5). The ten criteria aim to ensure indicators are clearly defined and based on an explicitly defined formula and source of data.

Main element	**Description**
Title	*Clear title for the measure*
Purpose	*The rational underlying the measure*
Relates to	*The business objectives to which the measure relates to*
Target	*An appropriate target for each measure should be recorded*
Formula	*The way the metric is measured*
Frequency	*The frequency with which performance should be recorded and reported*
Who measures?	*The person who collects and reports the data should be specified*
Source of data	*The source of the raw data should be specified*
Who acts on the data?	*The person who acts on the data should be specified*
What do they do?	*The management process to be followed should performance be acceptable or unacceptable*
Notes and comments	

Table 2-5 Performance measure record sheet [Neely *et al.,* 1997].

2.3.3. Key performance indicators in conventional product development

O'Donnell and Duffy [2005] argue that in comparison to areas such as manufacturing, the selection and use of KPIs in PD is more complex. During production, the focus is on more tangible outputs, i.e. physical goods and the activities are more easily understood. In PD, the activities can be unstructured and non-repetitive with less tangible outputs; making for a difficult environment to select and use a set of generic indicators [O'Donnell & Duffy, 2002, McGrath & Romeri, 2003, Costa *et al.,* 2014].

During a study to investigate the measurement of PD success and failure, Griffin and Page [1993] reviewed a total of seventy seven articles that identified measures used by researchers and conducted a survey including fifty respondents that identified measures used by practitioners during PD. A total of seventy five measures used by both practitioners and researchers were identified (see Appendix 1), which further illustrates the multidimensionality of success in PD. In a follow up study, Griffin and Page [1996] reduced these measures to a set of core measures by identifying the measures that were common across the studies. These were thought of as "the ones that everyone is using and wants to use" for measuring success and failure of conventional PD at the project-level. The measures could were then grouped according to the following high-level performance dimensions: Customer-based success; Financial success; and Technical performance success (see Table 2-6). The KPIs identified in Griffin and Page's study [1996] are a useful benchmark for this research project given the focus of the investigations for the measurement of success and failure at the project-level. They conclude that although identifying such measures and grouping them according to high-level performance dimensions can be useful for determining PD success, no one measure is useful for all projects and measuring PD success at the project-level requires certain flexibility. The difficulties in proposing a set of generalisable KPIs at the project-level in PD has been further highlighted in literature [Driva, 1997, Toor & Ogunlana, 2010].

Customer-based success	**Financial success**	**Technical performance success**
Customer satisfaction	Met profit goals	Competitive advantage
Customer acceptance	Met margin goals	Met performance specs
Market share goals	Return on investment	Speed to market
Revenue goals	Break-even time	Development cost
Revenue growth goals		Met quality specs
Unit volume goals		Launch on time
# of customers		Innovativeness

Table 2-6 Project-level success measures in conventional PD [Griffin & Page, 1996]

Krishnan and Ulrich [2001] and Hoegl *et al.* [2004] suggest that success in PD should be evaluated according to the following dimensions:

- Development time: the time taken to complete the PD project.
- Development cost: the costs associated with the completion of the project and development of the product.
- Product quality: the desired properties of the output developed by the PD team.

In several studies [Hoegl *et al.*, 2004, Van Oorschot *et al.*, 2005], these dimensions are referred to as resultants or dependent variables and provide indication towards what went right and what went wrong at the end of a process and hence, are lagging in nature. For example, when measuring the impact that inter-team coordination, project commitment and teamwork quality (independent variables) have on success in PD projects, the performance dimensions product quality, project budget and project time schedule (dependent variables) were used to provide indication at the end of the PD project to assess the impact these factors had on success [Hoegl *et al.*, 2004]. However, this approach to performance measurement has been described as a form of post mortem check [Tatikonda, 2007] and does not provide the feedback required to avoid deviations along the process as a result of influence factors such as inter-team coordination, project commitment and teamwork quality, which can otherwise be achieved with KPIs that are leading in nature. In fact, a general criticism of KPIs in PD is they are lagging in nature and provide a time-delayed retrospective look on performance, rather than an instantaneous evaluation or predictive insight required to make adjustments during the process [Driva, 1997, Tatikonda, 2007, Rhodes *et al.,* 2009].

According to O'Donnell and Duffy [2002], existing indicators of performance in PD are almost exclusively restricted to the achievement of design goals (the product/ outcome) rather than the activities necessary to develop the product (the process). For example, they do not consider the trade-off between the cost of the PD process and the quality of the final product. This approach focuses on the more tangible outcomes of PD and KPIs tend to relate to financial targets. Including both financial and non-financial KPIs to ensure a balanced approach to performance measurement is important. This is particularly emphasised in cases of high uncertainty, such as PD, where the relationship between input, process and output has been described to be less direct than in more generic business processes [Tatikonda, 2007, Taisch *et al.,* 2011].

Although the performance dimensions: development time; development cost; and product quality are undoubtedly important indicators of PD success and can provide indication towards what to improve for *future* PD projects, they fail to provide indication towards how to avoid deviations along the process of *current* PD projects. In PD projects, it is important to understand the key factors that influence the success of these dimensions, such as those in Table 2-1, and hence, provide the indication of where to make adjustments along the process to avoid missed deadlines or issues related to product quality for example.

2.3.4. Key performance indicators in global product development

Research toward the selection and use of KPIs in the context of GPD is relatively underdeveloped (refer to paper II for review of 59 articles of performance measurement in GPD). However in the supply chain management field, the added value of involving suppliers during PD activities has received much attention and a body of work focuses on the evaluation of supplier performance during the process of PD [Lohman *et al.,* 2004, Humphreys *et al.,* 2005, McKay *et al.,* 2013]. However, these focus on the supplier alone and the process of selecting indicators is not described. In the field of collaborative PD, studies have described the risks and opportunities involved with building global partnerships and conclude that it would be difficult to measure success given the higher significance of factors such as establishing clear objectives, communication issues and building trust between partners [Littler *et al.,* 1995, Emden *et al.,* 2006].

Selecting KPIs in conventional PD is a challenging task for project management and is further compounded in GPD [Taylor & Ahmed-Kristensen, 2013]. Factors influencing the success are accentuated and the inclusion of indicators that support the identification and avoidance of problems as they arise and hence, support decision making in GPD has been highlighted [Christodoulou *et al.*, 2007, Hansen & Ahmed-Kristensen, 2012]. Selecting and using lagging indicators commonly found in conventional PD, which provide a time-delayed retrospective look on performance, may not be managerially instructive for GPD.

2.3.5. Tools to support the selection of key performance indicators

KPIs are integral to a performance measurement system. Difficulties with proposing a set of generic KPIs in environments with high uncertainty, such as GPD, have been highlighted and therefore focussing on providing support for the selection of KPIs becomes increasingly important. Previous studies in the operations management field address this in relation to business processes in general. Early work saw the development of the Balanced Scorecard [Kaplan & Norton, 1992], which aims to provide a balanced approach to business performance measurement and considers financial and non-financial factors from four perspectives, namely: Customer, Internal, Financial, Learning and growth (refer to paper I for further explanation of the four perspectives in the Balanced Scorecard). However, the framework provided little support toward how a set of balanced KPIs could be realised in practice and hence, the same authors later proposed an eight-step approach to support the translation of a company's strategic objectives into a coherent set of KPIs (Figure 2-4). Through a number of workshops with executives at the company, the approach aims to support the creation of a balanced scorecard consisting of business-level KPIs. However during step seven in Figure 2-4, Kaplan and Norton [1996] highlight the requirement for a second level set of indicators but do not provide indication towards how these should be derived. Furthermore, the practicality of the eight-step approach has been questioned as the approach was found to result in open-ended and vague statements, rather than the selection of purposeful and measurable KPIs [Neely *et al.*, 2000].

1. Preparation:
   Identify the business unit for which a top-level balanced scorecard is appropriate.

2. Interviews - first round:
   Process facilitator interviews all the firm's senior managers and asks them to identify the company's strategic objectives and possible performance measures for the scorecard.

3. Executive workshop - first round:
   Senior management group debate the proposed mission and strategy statements until they reach a consensus. The process facilitator then asks the senior managers to answer the following question: "If I succeed with my vision and strategy, how will my performance differ for shareholders; for customers; for internal business processes; for my ability to innovate, grow and improve?" A draft balanced scorecard is developed on the back of this.

4. Interviews - second round:
   Process facilitator summarises the output from the first executive workshop and discusses it with each senior manager. The facilitator also seeks opinions about issues involved in implementation.

5. Executive workshop - second round:
   Larger workshop at which the senior managers and their direct reports debate the mission and strategy statements. "The participants, working in groups, comment on the proposed measures, link the various change programmes under way to the measures, and start to develop an implementation plan". Stretch targets are also formulated for each measure.

6. Executive workshop - third round:
   "The senior executive team meets to come to a final consensus on the vision, objectives, and measurements developed in the first two workshops; to develop stretch targets for each measure on the scorecard; and to identify preliminary action programmes to achieve the targets. The team must agree on an implementation programme, including communication of the scorecard to employees, integrating the scorecard into a management philosophy, and developing an information system to support the scorecard ".

7. Implementation:
   New implementation team formulates detailed implementation plan. This covers issues such as: how the measures can be linked to databases and information systems; how the scorecard can be communicated throughout the organization; and how a second level set of metrics will be developed.

8. Periodic reviews:
   Each quarter or month, a book of information on the balanced scorecard measures is prepared for both top management review and discussion with managers of decentralised divisions and departments. The balanced scorecard metrics are revisited annually as part of the strategic planning, goal setting, and resource allocation processes.

Figure 2-4 Designing a Balanced Scorecard [Kaplan & Norton, 1993]

The ten criteria proposed in the performance measure record sheet (illustrated in Table 2-5) were also used as a tool to provide structure for the selection of business-level KPIs in five manufacturing companies [Neely *et al.,* 1997]. When testing the record sheet, the criteria were presented to top executive at the companies, which created discussion between the developers of the record sheet and company executives in relation to the purposefulness and measurability of the companies' current KPIs at the business-level. Neely *et al.* [1997] concluded that discussing the criteria acted as a useful tool to explore what constitutes a well-designed indicator, rather than providing a structured approach to the selection process specifically. Building on this, Neely *et al.* [2000] propose six desirable characteristics when designing KPIs:

1. Indicators should be derived from the company's strategy
2. The purpose of the indicator must be made explicit
3. Data collection and methods of calculating performance must be clear
4. All stakeholders must be involved in the selection of the indicators
5. The indicator should take account of the organisation
6. The indicators should change as circumstances change.

Folan and Browne [2005], Mendibil and Macbryde [2007] and Barr [2014] propose similar recommendations for developing and selecting KPIs that focus on deriving KPIs from strategic level objectives and can be referred to in more detail in paper IV. However, these approaches provide support for the selection of KPIs at a business-level and have been criticised in relation to their practicality in environments such as GPD [Driva *et al.,* 2000, O'Donnell & Duffy, 2002, Molleman, 2007, Taylor & Ahmed-Kristensen, 2013].

Summary

Performance measurement has been described as a practical method to support decision making; with the selection and use of KPIs integral to such process. This is challenging in conventional PD and is further compounded by GPD and research in this area is underdeveloped. The selection and application of KPIs in accordance with the achievement of design goals, which typically result in lagging KPIs and is a common approach described for performance measurement in conventional PD, may not be sufficient given the additional challenges that influence success along the process in GPD. The importance of selecting KPIs according to factors that influence the success of a process and drive performance (leading indicators), rather than those that solely measure the outcome (lagging indicators), has been highlighted [Kaplan & Norton, 1996, Neely *et al.,* 2005, O'Donnell & Duffy, 2005, Rhodes *et al.,* 2009] and is further elaborated on in papers III and IV. Finally, the practicality of frameworks that focus on supporting the selection of KPIs for business processes in general has been criticised in the context of GPD.

2.4 Conclusions

Research on performance measurement in PD is relatively underdeveloped, particularly when parts of PD are globally distributed. To investigate this, the theoretical underpinning of the thesis comes from two perspectives, namely: engineering design, where key concepts from the fields of conventional PD [Hales, 1987, Badke-Schaub & Frankenberger, 1999, Ulrich & Eppinger, 2011] and GPD [Eppinger & Chitkara, 2009, Hansen & Ahmed-Kristensen, 2012] are reviewed; and operations management, where the focus turns to the selection and application of KPIs for business processes in general [Kaplan & Norton, 1996, Neely *et al.*, 2000, O'Donnell & Duffy, 2002]. The main conclusions from each of these domains are summarised here.

In conventional PD, success at the project-level is multifaceted and dependent on the environment in which it operates and the many different stakeholders involved during the process. The need for additional dimensions when determining success to those in the traditional Iron Triangle, namely; time, cost, and quality has been highlighted for assessing the less tangible outputs of PD activities [Wang, *et al.*, 2010, Toor & Ogunlana, 2010, Snider *et al.*, 2016]. The large number of factors identified that influence success in PD projects (Table 2-1) further indicates the multidimensionality of this topic. Identifying factors that *influence* success is useful for developing preventative measures for researchers and practitioners [Badke-Schaub & Frankenberger, 1999] and hence; can support the management and monitoring of PD projects.

Globalising parts of PD adds further complexity to the PD environment and managing culturally diverse and geographically dispersed engineering teams during GPD accentuates the many factors that influence success typically found in conventional PD [Hansen & Ahmed-Kristensen, 2011, Anderson & Parker, 2012]. A number of studies investigate the high-level challenges companies encounter during GPD [Eppinger & Chitkara, 2009, Hansen & Ahmed-Kristensen, 2011, Kalyandurg & Akhilesh, 2012] and this area of research is beginning to mature. However, these studies typically consist of interviews or observations of short design sessions and do not provide the in-depth insight required to investigate the impact that such challenges may have on GPD at the project-level. Such understanding can support researchers and practitioners to develop precautionary measures and hence, avoid the learning-by-doing approach to managing GPD projects that has previously been observed in several industrial case studies [Barthelemy, 2003, Hansen & Ahmed-Kristensen, 2011].

The need for developing KPIs to support the identification and avoidance of problems as they arise and hence, support decision making in GPD has been highlighted [Christodoulou *et al.*, 2007, Hansen & Ahmed-Kristensen, 2012]. However, to the authors' knowledge there are few studies that investigate this in the context of GPD. A criticism towards KPIs applied in conventional PD projects is they are lagging in nature and typically focus on measuring the outcome of a process [Driva, 1997, Tatikonda, 2007, Rhodes *et al.*, 2009]. Although such indicators are useful in showing history and progress of an organisation's efforts, lagging indicators fail to provide information for predictive purposes, and hence do not allow management to take action before problems arise. Given the additional challenges in managing geographically dispersed engineering teams in GPD projects, the application of lagging KPIs alone may be inadequate to inform management of where to make adjustments to avoid deviations along the process. The importance of developing KPIs according to factors that influence the success of a process (leading KPIs), rather than those that solely measure the outcome of a process (lagging KPIs), has been highlighted [Kaplan & Norton, 1996, Neely *et al.*, 2005, Rhodes *et al*., 2009].

To summarise, the literature review highlighted that research towards performance measurement has focussed on business processes in general and there exists a need to further understand the current practice for performance measurement in GPD at the project-level. Furthermore, the key challenges in GPD illustrated in Table 2-3 are high-level issues and there are few studies that investigate how such challenges influence the success at a project-level in GPD. The importance of understanding key challenges that influence success of a process, rather than those that solely focus on the achievement of design goals (such as the motivations in Table 2-2), has been highlighted from several sources in literature to support the development of precautionary measures [Neely *et al.*, 2005, Rhodes *et al.*, 2009, Wang *et al.*, 2010].

Figure 2-5 illustrates the relationship between key topics covered in the literature review. The key areas for further investigation are indicated in red.

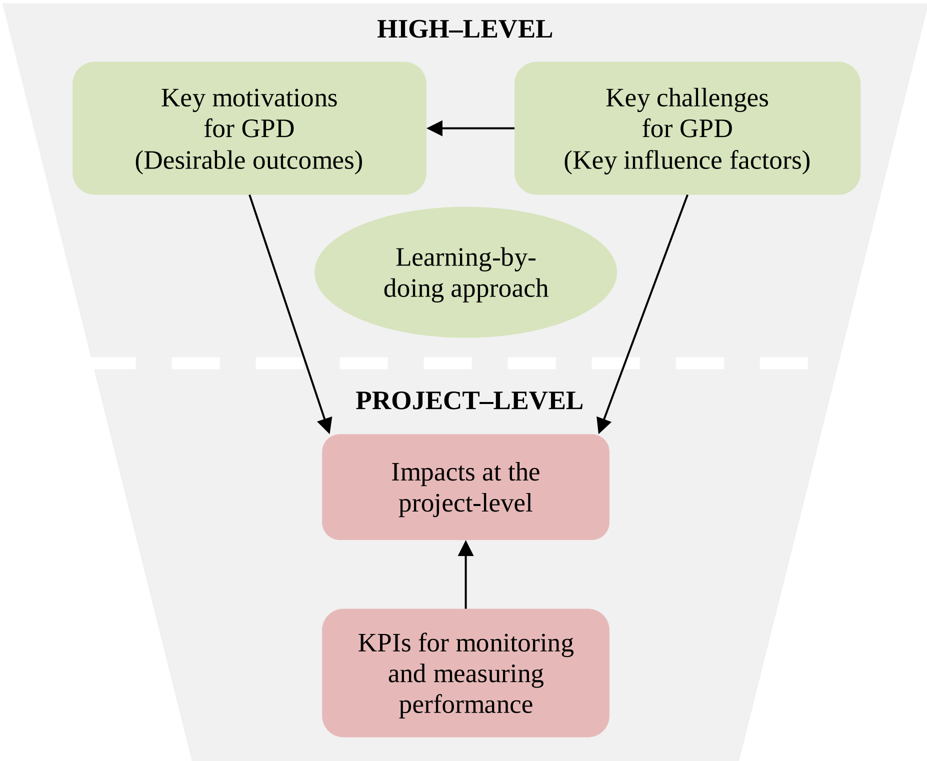

Figure 2-5 Key topics covered in the literature review and the areas that require further investigation

A need was identified to understand the key factors influencing success in GPD at the project-level and the current practice for the selection and application of KPIs. This understanding could provide the basis for the development of a method to support performance measurement in GPD and allow for informed decision making along the process. These conclusions informed the research approach for this thesis, which is described in the subsequent chapter.

Chapter 3 Research Approach

This chapter describes the overall research approach and the empirical studies conducted for the project. This includes: the research questions and objectives formulated; the research methods employed to address these; a description of the participants involved; the limitations of the studies conducted; and the method of analysis for the studies.

3.1 Introduction

The overall research aim is to develop an understanding toward the current practice for performance measurement in global product development to support management in making informed decisions. The previous chapter discussed the literature, focussing on: conventional PD; global PD; and performance measurement in respect to the selection and use of KPIs. In GPD, studies exemplify how issues related to cultural differences and team proximity accentuate factors influencing success in comparison to conventional PD, and companies that adopt a learning-by-doing approach to GPD incur costs later in the process. Performance measurement, and in particular the selection and application of KPIs that monitor both negative and positive impacts on success, has been described as a practical method to support decision making along the process in GPD. However, there is a lack of studies that investigate the selection and application of KPIs at the project-level in GPD. A general criticism of KPIs used in conventional PD is they are lagging in nature and typically focus on the outcome of the process and hence, provide a time-delayed retrospective look on performance. Given the additional challenges experienced during the process of GPD, the use of lagging KPIs may be insuffient to provide the timely feedback on performance to allow adjustments to be made along the process and avoid challenges in GPD. Based on this, there is a need to develop an understanding towards the current practice for performance measurement in GPD at the project-level. Hence, empirical research in industry was selected as the most appropriate method to gain this understanding. This understanding can provide the basis for the development of a method to support performance measurement in GPD and allow for informed decision making along the process.

The overall research methodology adopted for this thesis is the Design Research Methodology (DRM) proposed by Blessing and Chakrabarti [2009]. The DRM offers a supportive framework for scientific inquiry and dialogue with industry in design research. In this research project, such dialogue is essential to ensure the fulfilment of the overall research aims. For example, based on the overall aims and conclusions drawn in Chapter 2, there was a need to understand the current practice of performance measurement in GPD projects and to develop a practical method to support this process. Given the explorative nature with both a descriptive and a prescriptive phase to ensure the present situation and possible improvements are uncovered, the DRM was considered an appropriate research methodology to support the fulfilment of the overall aims in this research project.

The methodology consists of four stages: Research clarification; Descriptive study I; Prescriptive study; and Descriptive study II (Figure 3-1). The four stages are described briefly in the following section in relation to this research and discussed in more detail throughout the thesis. The research clarification stage is the motivation for the research and is discussed in Chapter 1. The empirical studies and research methods employed at the descriptive study I, prescriptive study and descriptive study II stages are discussed in the following sections in Chapter 3. The results from the descriptive study I stage are discussed in Chapter 4. The results from the prescriptive study and descriptive study II stages are discussed in Chapter 5.

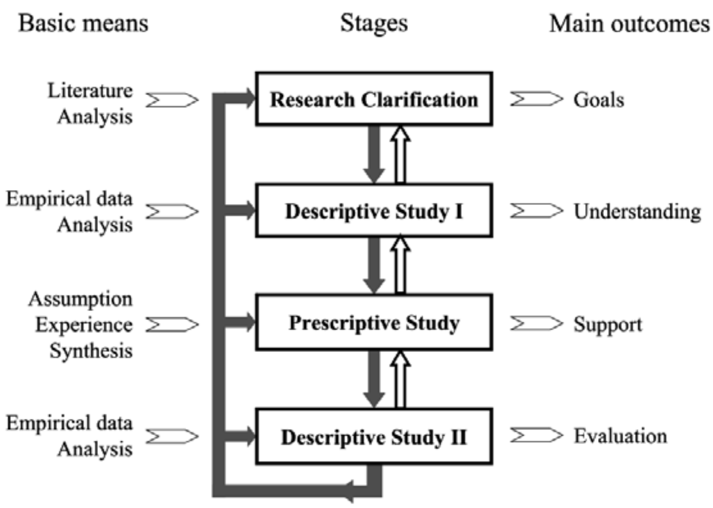

Figure 3-1 Stages of the Design Research Methodology Blessing and Chakrabarti [2009]

For this research project, the four main stages from the DRM are described below together with the empirical studies conducted. The empirical studies conducted are described in more depth in Chapter 3 section 3.3.

<u>Research clarification:</u> The overall aim of design research is to understand how designers produce successful products and hence develop methods and tools to support them. Performance measurement has been identified as a key criteria for success in GPD to support decision making

[Christodoulou *et al.*, 2007, Hansen & Ahmed-Kristensen, 2012] see Chapter 2 section 2.4. Specifically, the selection and application of KPIs that support the identification and avoidance of problems as they arise and hence, support decision making in GPD has been highlighted [Christodoulou *et al.*, 2007, Hansen & Ahmed-Kristensen, 2012].

<u>Descriptive study I:</u> Blessing and Chakrabarti [2009] state that descriptive studies should be carried out to understand more deeply the criteria for a successful product, in this case, performance measurement in GPD projects. Empirical research was carried out in order to understand the selection and application of KPIs and the factors influencing the success in GPD at a project-level. This understanding can then be used to support project management in selecting KPIs to support the identification and avoidance of problems as they arise and hence, enable informed decision making along the process. The following research studies were conducted at the descriptive study I stage:

- Study one: Exploratory study
- Study two: Multiple case studies.

<u>Prescriptive study:</u> During the prescription stage a method was developed to support the identification of key factors influencing success in GPD projects and provide a structured approach for the selection and documentation of KPIs to monitor and measure these. The method of support was developed based upon the key findings in the descriptive study I stage. The development of the support method is described in Chapter 5.

<u>Descriptive study II:</u> Blessing and Chakrabarti [2009] suggest a further study to investigate the impact of the proposed support method in realising the intended improvement. A further research study was conducted at this stage with a third company case to evaluate the proposed support method. The evaluation included: (1) the validation of the support method; (2) the reaction of the project team to the support method; (3) the key principals learned from the use of the support method; (4) the impact of the support method on the behaviour of the project team; and (5) their results. The following research study was conducted at the descriptive study II stage:

- Study three: Evaluation of support method

Figure 3-2 illustrates the structure of this thesis and describes the chapters in relation to the stages of the DRM outlined previously.

The parts of the project that have been presented so far are included in Figure 3-2. These are: the motivation for the project as discussed in Chapter 1 section 1.1; the main aims and research questions for the project as discussed in Chapter 1 section 1.2; and the main conclusions drawn from the literature review as discussed in Chapter 2 section 2.4.

An overview of the research methods employed for the three empirical studies are presented in section 3.3 and discussed in more detail in sections 3.5, 3.6 and 3.7 in Chapter 3. The results from the empirical studies conducted at the descriptive study I stage are presented in Chapter 4. The results from the prescriptive study and descriptive study II are presented in Chapter 5.

The seven papers written during this research project are also illustrated in Figure 3-2. The seven papers contribute as a whole, or as excerpts to, the different elements and stages of the project. These contributions are briefly mentioned in Figure 3-2 and are referred to throughout the report of this project (refer to Appendix 5 for the seven papers).

The following section discusses the research questions, which were formulated in accordance with the main aims of the research project and the stages of the DRM. The research questions form the basis for the empirical studies conducted in this research project.

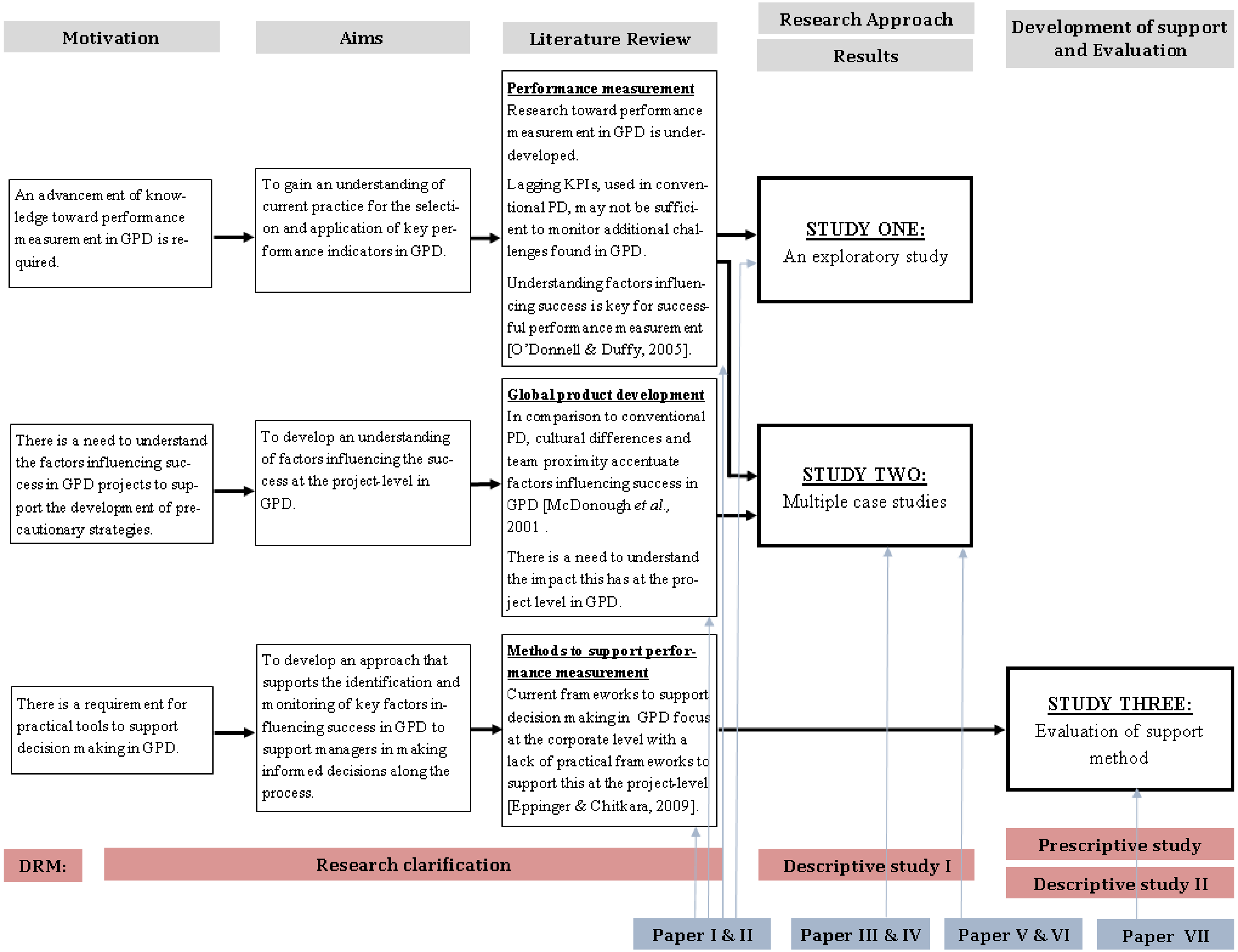

Figure 3-2 Outline of thesis in relation to project aims, research approach and papers written

3.2 Research questions

The overall research aim is to develop an understanding toward the current practice for performance measurement in GPD at the project-level to support management in making informed decisions. The specific aims of this research project were:

- To gain an understanding of current practice for the selection and application of key performance indicators in GPD.
- To develop an understanding of factors influencing the success of GPD.
- To develop an approach that supports the identification and monitoring of key factors influencing success in GPD projects to support managers in making informed decisions along the process.

To address these aims, the specific research questions and objectives formulated for this research project are presented in Table 3-1 according to the DRM stage they address. In addition, the seven papers written during this research project are mapped according to the research questions they contribute to. The research questions are discussed in accordance with conclusions drawn from the literature review in the following sections.

DRM Stage:			
Research clarification	Descriptive study I	Prescriptive study	Descriptive study II
Research questions:			
(1) What is the current practice for measuring performance in conventional and global PD projects?	(2) How are KPIs used to monitor factors influencing success in GPD projects?	(3) How to support the selection of KPIs that provide project management with timely feedback on performance?	(4) How does the proposed method support the process of selecting KPIs in GPD projects?
Research objectives:			
(1) A. Identify KPIs used in GPD projects. **- Paper I**	(2) A. Elucidate the current practice for selecting KPIs in GPD. **- Paper III + IV**	(3) A. Develop a method that supports the identification and prioritisation of critical factors influencing success in GPD projects. **- Paper VII**	(4) A. Evaluate how the proposed method supports the selection of both leading and lagging KPIs in GPD. **- Paper VII**
(1) B. Investigate how the KPIs cohere with challenges and motivations specific to GPD. **- Paper II**	(2) B. Investigate how KPIs monitor both the negative and positive impacts in GPD at a project-level. **- Paper III + IV**	(3) B. Develop a method that supports the selection and documentation of leading and lagging KPIs in GPD projects. **- Paper IV + VII**	(4) B. Evaluate how the proposed method supports the early identification of critical factors influencing success in GPD projects and supports to minimise the risk towards these. **- Paper VII**
	(2) C. Identify the key factors influencing success in GPD at a project-level. **- Paper V + VI**		

Table 3-1 Research questions and objectives formulated according to the stages of the DRM

Research question (1): research toward performance measurement in GPD is underdeveloped and there is a need to understand if concepts from current frameworks that focus on business processes in general can be adapted within the context of GPD [Christodoulou *et al.*, 2007, Anderson & Parker, 2012]. As a result, the objectives for research question one focus on identifying the current practice for performance measurement, with a focus on the use of KPIs, and their applicability within the context of GPD. This is addressed in paper I and II, which discuss the coherence of KPIs selected in accordance with key motivations and challenges in GPD and current performance measurement frameworks found in literature. The contributions indicate that goal-oriented approaches to performance measurement typically found in conventional PD do not provide sufficient means to monitor the challenges in GPD and hence, there is a requirement for an alternative approach to support performance measurement in GPD.

<u>Research question (2):</u> performance measurement in conventional PD is challenging and is further compounded by GPD [Taylor & Ahmed-Kristensen, 2013]. Understanding factors influencing success and selecting KPIs according to these has been described as the “holy grail” for successful performance measurement [O’Donnell & Duffy, 2005]. Therefore, there is a need to understand how KPIs are used to monitor factors influencing success in GPD projects. Based on this, the objectives for research question two investigate the selection and application of KPIs and how the KPIs monitor challenges and motivations in GPD projects and is addressed in paper III, IV and partially in VII. In addition, paper V and VI identify the key factors influencing success in GPD and the cause-effect relationship of these factors at the project-level. The contribution indicates that current approaches for selecting KPIs in GPD projects result in KPIs that are lagging in nature, which are common in conventional PD, and do not provide the predictive feedback required to monitor factors influencing success and inform management of the necessary strategies to be set to minimise specific risks that are common in GPD projects.

<u>Research question (3):</u> there is a need for practical frameworks that support decision making in GPD [Eppinger & Chitkara, 2009, Hansen & Ahmed-Kristensen, 2012]. Performance measurement has been identified as a practical method used to provide accurate feedback on the performance of a process and support decision making [Neely *et al.*, 2000, O’Donnell & Duffy, 2002, Nenadál, 2008]. The objectives for research question three focuses on developing support for performance measurement in GPD with a focus on the selection and application of KPIs that provide predictive feedback to support the avoidance of problems as they arise. These comprise the assessment of conditions and the design of the approach to developing the support: paper IV and VI investigate the requirements and conditions of use for a method of support for performance measurement in GPD, and paper VII proposes a method of support to address the selection of KPIs in GPD projects. There is a requirement to support the development of leading and lagging KPIs to provide accurate

and timely feedback to support (and if necessary adjust) GPD decisions along the process. Such KPIs are developed with the early identification and prioritisation of key factors influencing success in GPD projects.

The objectives for research question four address the verification of support for selecting both leading and lagging KPIs in GPD that minimise the impacts as a result of the challenges in GPD in addition to KPIs selected that are goal-oriented, thereby validating the proposed support in this research project. The verification of the proposed support was conducted by means of a KPI selection workshop in a real project situation in industry. Paper VII evaluates the impact of the proposed support on the process of selecting leading and lagging KPIs, and how precautionary strategies are developed to avoid factors influencing success as a result of this selection process.

The following sections in Chapter 3 describe the empirical studies conducted during the descriptive study I stage to address the research questions and objectives of this research project.

3.3 Empirical studies in this research project

When planning the empirical research, several research methods from the social sciences were investigated when conducting the three empirical studies. The methods were selected based on the extent to which they fulfilled the criteria established by the research aims and also their practicality. The fulfilment of the following research aims was considered:

- To gain an understanding of current practice for the selection and application of key performance indicators in GPD.
- To develop an understanding of factors influencing the success of GPD.
- To develop an approach that supports the identification and monitoring of key factors influencing success in GPD projects to support managers in making informed decisions along the process.

The following issues in relation to conducting empirical studies in industry were considered:

- To maintain the confidentiality of the participants in the research study.
- To keep the amount of time and involvement of the participants in the research study at a reasonable level to ensure minimal disturbance toward their day-to-day activities.

- To seek permission from the participants before audio or video-recording.

To develop an understanding toward performance measurement in GPD, the research was carried out in a natural environment in industry. Studies carried out in their natural environment, as opposed to protocol studies in the laboratory, provide in-depth understanding of real time tasks and activities that lead to creative insights of high validity for practitioners [Voss *et al.*, 2002, Ahmed-Kristensen, 2007]. Two studies were conducted to address the research questions and specific objectives at the descriptive study I stage, namely: Study one: Exploratory study; and Study two: Multiple case studies. One study was conducted to address the research questions and specific objectives at the descriptive study II stage, namely: Study three: Evaluation of support method. The research in this project was data driven and the knowledge gained from each study influenced the direction of the subsequent studies. A combination of research methods were adapted for the studies as multiple sources of evidence increase the reliability of data [Yin, 2009]:

- <u>Study one:</u> Exploratory study - two cross-company surveys that were exploratory in nature were conducted including an online and a paper-based survey and provided an understanding of current practice for performance measurement in GPD across a broad range of Danish manufacturing companies.
- <u>Study two:</u> Multiple case studies - interviews, observations and document analysis were conducted in two large Danish manufacturing companies and provided a more in-depth understanding to fully investigate the aims of the research project.
- <u>Study three:</u> Evaluation of support method – a workshop, surveys and interviews were conducted in a large Danish manufacturing company, enabling the implementation and evaluation of the support method developed as a result of the key findings from the descriptive study I stage.

The multiple research methods employed in the two studies provided different levels of understanding and hence, contributed to the different stages of the research project, which is discussed in more detail in Chapter 3 sections 3.5, 3.6 and 3.7.

Table 3-2 illustrates an overview of the research methods employed to address the research objectives at the different stages of this research project.

A structure for the collection of data was developed and redefined as the project progressed based on the ongoing analysis and reflection of data. The three empirical studies are discussed further in the following sections in relation to their research methods, the participants, the limitations and method for analysis.

DRM stage:			
Research clarification	Descriptive study I	Prescriptive study	Descriptive study II
Research objectives:			
(1) A. Identify KPIs used in GPD projects. **(1) B.** Investigate how the KPIs cohere with challenges and motivations specific to GPD.	**(2) A.** Elucidate the current practice for selecting KPIs in GPD. **(2) B.** Investigate how KPIs monitor both the negative and positive impacts in GPD at a project-level. **(2) C.** Identify the key factors influencing success in GPD at a project-level.	**(3) A.** Develop a method that supports the identification and prioritisation of critical factors influencing success in GPD projects. **(3) B.** Develop a method that supports the selection and documentation of leading and lagging KPIs in GPD projects.	**(4) A.** Evaluate how the proposed method supports the selection of both leading and lagging KPIs in GPD. **(4) B.** Evaluate how the proposed method supports the early identification of critical factors influencing success in GPD projects and supports to minimise the risk towards these.
Research approach guidelines:			
Conduct an exploratory study focussed on coherence of KPIs with key motivations and challenges in context of GPD.	Conduct in-depth multiple case studies focussed on the selection and application of KPIs and factors influencing success in GPD at the project-level.	Utilise findings from the empirical studies to develop a method to support the identification and monitoring of key influence factors in GPD projects.	Conduct a case study with practitioners in industry to validate the proposed support.
→ Goal formulation	**→ Describe situation**	**→ Propose intervention**	**→ Preliminary evaluation**
Study one: Survey I Survey II	**Study two:** Interviews Observations Document analysis	**Development of support**	**Study three:** Workshop Interviews Surveys

Table 3-2 Research methods employed during three studies to address the research questions

3.4 Characteristics of the empirical studies

Characteristics have been identified by Blessing and Chakrabarti [2009] to describe the nature of a research study. These characteristics need to be considered when assessing the findings of a particular study. The three empirical studies conducted during this research project, namely: Study one: Exploratory study; Study two: Multiple case studies; and Study three: Evaluation of support method are mapped according to these characteristics in Table 3-3. As multiple research methods were used within the individual studies, the specifics of each method are separated for each of the characteristics. In summary:

- The two studies conducted during the descriptive study I stage were exploratory in nature since no prescriptive methods or tools were introduced.
- The environment for the three empirical studies was industry and the subjects were engineers from large Danish manufacturing companies with parts of their PD process globally distributed. However, the environment for the paper-based survey (Survey II) conducted in study one was the laboratory and was held with a focus group including top and middle level management from large Danish manufacturing companies during a workshop that focussed on GPD.
- Two case studies with large Danish manufacturing companies (Company A and Company B) were investigated in study two, which included direct observations, semi-structured interviews and the analysis of company documentation.
- The remaining characteristics varied with each of the three studies and are discussed in detail in the following sections in Chapter 3.

Characteristics	**Options**	**Characteristics of studies conducted**							
		Study one: Exploratory study		Study two: Multiple case studies					
				Company A			Company B		
Nature of the study	Observational or interventional (*i.e.*, whether the study involved intervention in the design process by the researcher), comparative or non-comparative	Exploratory, non-comparative research							
Data collection methods	The method(s) used, such as direct observation, participant observation, document analysis, survey, interview	Survey I	Survey II	Semi-structured interviews	Direct observations	Document analysis	Semi-structured interviews	Direct observations	Document analysis
Environment	Industry or laboratory	Industry	Laboratory	Industry					
Subjects	Nationality	28 Danish companies	16 Danish companies	8 Danish engineers, 4 Indian engineers		Company documents	3 Danish engineers, 6 Chinese engineers, 2 Polish engineers		Company documents

Number of cases	Number of data sets collected, *e.g.*, the number of experiments, interviews, observed groups, products	27 Survey respondents	17 Survey respondents	12 interviewees	27 observations (project meetings)	n/a	11 interviewees	7 observations (project meetings)	n/a
Duration	Length of process studied	n/a		45-60 minutes per interview	30-90 minutes	n/a	45-60 minutes per interview	60 minutes. 1meeting was 2 day project workshop.	n/a
Observed stage of PD process	Starting point of the observed process	n/a		From initial proposal (planning stage) to completion of testing before production			From initial proposal (planning stage) to near completion of detail design		
Task	Nature of the observed tasks: real, realistic or artificial	Real							
Role of researcher	Type of involvement of the researcher in the research process	Facilitator		Interviewer	Non-participative observer	n/a	Interviewer	Non-participative observer	n/a
Design Object type	Original, variant or redesign	n/a		Variant					
Batch size	Mass, large batch, small batch, one-off	n/a		Small					

Table 3-3 Characteristics of studies conducted during the descriptive study I stage

The research issues for the empirical studies conducted during this research project are discussed in the following sections. For the three studies: an exploratory study; multiple case studies; and Evaluation of support method, the following are covered:

- The research methods employed in general (e.g. section 3.5 Study one: Exploratory study)
- The use of the research method for this study (e.g. section 3.5.1 Description of exploratory study)
- The specific characteristics of the study (e.g. section 3.5.2 Exploratory study: Experimental setup)
- The participants involved in the study (e.g. section 3.5.3 Exploratory study: The participants)
- The limitations of the approach (e.g. section 3.5.6 Limitations of exploratory study)
- The method of analysis for the study (e.g. section 3.5.7 Exploratory study: Analysis method).

3.5 Study one: Exploratory study

Two surveys were conducted in study one to address the research objectives at the descriptive study I stage (see Table 3-2). First, issues surrounding surveys and their design are discussed in general before describing the use of surveys specific for this research study. Parts of the study can be referred to in paper I and II (Appendix 5).

A survey is a group or sequence of questions designed to obtain information about characteristics of interest from some or all units of a population [Statistics Canada, 2010]. A survey usually begins with the need for information where no data, or insufficient data, exist. They are often sent by mail and increasingly by internet, but also used in telephone surveys and surveys in public places [Blessing & Chakrabarti, 2009]. Basic approaches for data collection from a survey are self-enumeration i.e. the respondent completes the survey without assistance, and interviewer assisted through personal or telephone interviews. Surveys, and in particular those that adopt self-enumeration for data collection, require limited resources to administer. However, the quality of data may be lower when no assistance or interviewer is provided. Furthermore, ensuring a statistically representative sample of respondents can be challenging and failure to do so can lead to ambiguous and non-significant results [Eckert & Summers, 2013]. The survey must be well-designed and user friendly to encourage participation and reduce response errors and participant bias.

3.5.1. Description of exploratory study

The aim of this study was to develop an understanding of current practice for measuring performance of PD when parts of the process are globally distributed, addressing research question 1 in section 3.2. The specific objectives of the study were:

a) To identify KPIs used in GPD projects.
b) To investigate how the KPIs cohere with challenges and motivations specific to GPD.

To investigate this, two surveys were conducted with a total of 44 Danish manufacturing companies that currently globalised parts of their PD process (see Table 3-3 for characteristics of study one). The two surveys were exploratory in nature to gain key insights towards the current practice of performance measurement in the GPD context and to guide the direction for the subsequent studies in this research project. The first survey: Survey I included responses from 28 companies and focussed on key motivations for GPD and KPIs used according to these. The second survey: Survey II included responses from 16 companies and focussed on key motivations and challenges for GPD and KPIs used according to these. The specific use of these methods in study one is presented separately according to Survey I and Survey II in the following sections.

- First, the experimental setup and the participants of Survey I are discussed in more detail in sections 3.5.2 and 3.5.3 respectively.
- Second, the experimental setup and the participants of Survey II are discussed in more detail in sections 3.5.4 and 3.5.5 respectively.

The two surveys are discussed together in relation to the limitation of the research methods and analysis method in sections 3.5.6 and 3.5.7 respectively.

3.5.2. Exploratory study: Experimental setup of Survey I

The survey consisted of three sections: (1) background information about the respondent and the participating companies; (2) their motivation(s) for GPD; and (3) the KPIs used for measuring performance (refer to Appendix 2 for the questions asked in Survey I). Open ended and multiple choice questions were used within each of these sections. For the motivations for GPD, respondents were asked to state the motivations for outsourcing or offshoring stages of PD. This was an open ended question. It was of interest to capture the motivations for GPD from respondents as a fundamental principle for the design of KPIs was: KPIs should be derived from strategic objectives [Kaplan & Norton, 1996, Neely *et al.*, 2000] see Chapter 2 section 2.3.5. Capturing the companies' motivations for GPD enabled for coherence between the motivations and the selected KPIs for measuring performance to be analysed, addressing research question 1 in section 3.2. For the KPIs used for measuring performance, respondents were asked to select KPIs currently used for measuring performance in GPD. Multiple choice questions were used for capturing the KPIs. The possible answers to the multiple choice questions were structured related to core KPIs for measuring success and failure in conventional PD projects identified during the literature review of this research project (see Table 2-6) as a comprehensive set of KPIs specific for GPD could not be identified at the time of research. Furthermore, the core KPIs in Table 2-6 were the result of a comprehensive review of literature and an empirical study that focussed on identifying KPIs specifically at the project-level and hence, represented a close fit to the aims of this research project. However, an "other" checkbox provided participants with the opportunity to include KPIs that were not related to common KPIs in conventional PD projects and hence, more specific to GPD.

Survey I was an online survey and was completed without assistance. To minimise the response error, a pilot survey was sent to a smaller sample of respondents that were both internal and external from the research project to identify any difficulties with the questions. This resulted in minor adjustments to the user-interface before the final survey was distributed. The survey was kept short, approx. 10 minutes, to increase the response potential.

3.5.3. Exploratory study: The participants in Survey I

The survey was distributed to 100 companies in Denmark who currently globalised parts of PD. 38 surveys were distributed to companies from a previously established interest group, characterised by their high involvement with GPD activities and their interests in developing tools to manage such collaborations. The remaining 62 were passed to The Danish Industry Foundation, who distributed the surveys to Danish companies with experience in GPD. 28 responses were received consisting of 19 large, 2 medium and 7 small sized companies from the manufacturing and product development sector in Denmark and participants ranged from senior to middle management level (see Table 3-4 for participant characteristics).

Company characteristics		
Size:	Small (<50)	7
	Medium (50-250)	2
	Large (>250)	19
	Total no. of companies	**28**
Industry sector:	Manufacturing	17
	Information Technology	9
	Energy	2
	Total no. of companies	**28**
Position:	Senior management	14
	Middle management	14
	Total no. of companies	**28**

Table 3-4 Participants in Survey I during the exploratory study

3.5.4. Exploratory study: Experimental setup of Survey II

The approach to research in this project was data-driven and hence, the knowledge gained from Survey I influenced the design of Survey II. The survey consisted of four sections: (1) background information about the respondent and the participating companies; (2) their motivations for GPD and challenges with GPD; (3) the strategies employed for achieving the motivations and avoiding the risks posed by the challenges; and (4) the KPIs used for measuring and monitoring the previously stated motivations and challenges (refer to Appendix 2 for the questions asked in Survey II). Open ended and multiple choice questions were used within each of these sections. In addition to survey I, respondents in survey II were asked to state the challenges they experienced with GPD. It was of interest to capture the challenges given the importance expressed in literature of selecting KPIs that provide predictive insight in relation to the identification and avoidance of problems as they arise [Hansen & Ahmed-Kristensen, 2012] see Chapter 2 section 2.2.4. Understanding key challenges for GPD enabled for coherence between the challenges and the stated KPIs for measuring performance to be analysed, addressing research question 1 in section 3.2. Based on the results from Survey I and the maturity of the literature that investigates the challenges and motivations for GPD, see Chapter 2 section 2.2.2, key challenges and motivations highlighted in literature for GPD were provided as possible answers for the first section of the survey and the respondents were asked to rank these in order of importance (see Table 2-2 for motivations included and Table 2-3 for challenges included in Survey II). An ‘other’ category was provided to capture motivations and challenges in addition to the possible answers provided. Following this, the strategies employed for achieving the motivations and avoiding the risks posed by the challenges was included as an open ended question. This section to the survey was included as such approach has been recommended to support the selection of KPIs by previous authors [Kaplan & Norton, 1992, Neely *et al.*, 2000]. This was considered necessary as unlike in Survey I, where respondents were provided with possible answers to select KPIs for measuring performance in GPD, in Survey II an open ended question was used for this section of the survey and respondents were asked to state the KPIs used for measuring and monitoring the motivations and challenges for GPD that they had previously selected and ranked.

Survey II was a paper-based survey completed during an industrial workshop that focussed on performance measurement in GPD. The workshop was held as part of this research project. The workshop was held with members from the previously established interest group. The survey was kept short, approx. 10 minutes, and the researcher assisted the respondents in completing the survey when necessary. This helped to minimise the response errors and maximise the response potential. Prior to completing the survey, the respondents were given 5 minutes to consider a recent GPD project they had been involved with to be used as a reference for completing the sections of the survey.

3.5.5. Exploratory study: The participants in Survey II

The participants at the workshop were from a previously established interest group, characterised by their high involvement with GPD activities and their interests in developing tools to manage such collaborations. All participants at the workshop completed the survey, which included 17 respondents from 16 different Danish companies. The companies were from the engineering manufacturing sector and included 6 large, 5 medium and 5 small sized companies. Similar to Survey I, the participants ranged from senior to middle management level (see Table 3-5 for participant characteristics).

Company characteristics		
Size:	Small (<50)	6
	Medium (50-250)	5
	Large (>250)	6
	Total no. of companies	**16**
Industry sector:	Manufacturing	14
	product development	2
	Electronics	1
	Total no. of companies	**16**
Position:	Senior management	6
	Middle management	11
	Total no. of companies	**16**

Table 3-5 Participants in Survey II during the exploratory study

3.5.6. Limitations of the exploratory study

The two surveys, which form the data collection methods in study one, were distributed to engineering manufacturing companies in Denmark that currently globalised parts of their PD process. At the time of research, the number of Danish companies that met these criteria was unknown and therefore, it was difficult to assess whether the number of participants in study one reflected a statistically representative sample. However, as the two surveys were exploratory in nature to gain key insights towards current practice of performance measurement in the context of GPD and to guide the direction for the subsequent studies in this research project, the number of participants was deemed adequate to gain this initial understanding.

The environment where the two surveys were completed was different, i.e. Survey I was completed without assistance and Survey II was completed with the assistance of the researcher. With the assistance of the researcher during Survey II, response bias may have increased. However in general, it was found that the quality of data may be lower when no assistance is provided during the completion of surveys [Statistics Canada, 2010]. Table 3-6 presents the validity of the answers received from Survey I and Survey II. In Survey I, the validity of the answers provided by the participants was relatively high and can to some extent be explained given the high number of multiple choice questions available for participants to choose from in the survey. The percentage of valid answers provided by participants in Survey II was also high. The majority of the invalid answers were in relation to the participants stating KPIs for monitoring the key motivations and challenges in GPD and is discussed further in Chapter 4 section 4.1.1.

	Survey I	Survey II
Total answers	280	276
Total deleted answers	44	60
- Invalid answers	7	31
- Incomplete answers	25	22
- Repeated answers	12	7
Valid answers	236 (84.3%)	216 (78.2%)

Table 3-6 Overview of deleted answers from Survey I and Survey II

Providing participants with a list of factors, for example the KPIs in Survey I and the key challenges and motivations in Survey II influenced the answers provided by the participants. In both surveys, the option to state "Other" was used in the multiple choice questions to ensure the participants were not limited to the factors provided.

In general, data collected from surveys does not provide the richness or in-depth contextual understanding that can otherwise be gained by conducting interviews or observational studies for example.

3.5.7. Exploratory study: Analysis method

A coding scheme was developed as the study progressed to analyse results from study one. Key aspects recommended by Braun and Clarke [2006] for the development of coding schemes were adopted. Themes in the coding scheme were developed based on key patterns that emerged from the literature review, the two surveys conducted and the specific research objectives for the study, which were outlined in section 3.5.1. The four main themes developed in the coding scheme for the exploratory study were: (1) key motivations for GPD; (2) key challenges with GPD; (3) strategies to achieve or avoid key challenges and motivations for GPD; and (4) KPIs for measuring and monitoring key challenges and motivations (see Figure 3-3). Data collected from Survey I and II were grouped according to these main themes. In survey I, data was not collected according to all four themes as additional themes were created as the exploratory study progressed. Following the grouping of data according to the four themes, the data were categorised within these themes according to a more specific set of codes. The codes were developed based on the literature review and also key patterns emerging from the empirical study; so as to avoid the confinement of data (see Table 3-15 in Chapter 3 section 3.6.8 for the specific codes used during the analysis of the exploratory study). For example, research toward key motivations and challenges for GPD is maturing and therefore, the majority of codes within these themes were developed based on challenges and motivations identified in Chapter 2 section 2.2.2. However, research towards performance measurement in GPD is relatively underdeveloped and therefore, a number of codes for the stated KPIs were generated based on the empirical data. If a KPI was stated more than once by the respondents in Survey I and II, which could not be categorised according to common KPIs in conventional PD projects [Griffin & Page, 1996], a new code was generated. A coder-reliability check was conducted for this process with two researchers that were familiar with the area of research, which indicated a strong validation coefficient: 0.78, i.e. the coding of the data was not subjective, and can be referred to in paper II. The final codes were counted for frequency of occurrence to highlight interesting patterns in the data. The analysis of the coded data is comparable to approaches adopted by Mintzberg and McHugh [1985] and Eisenhardt [1989].

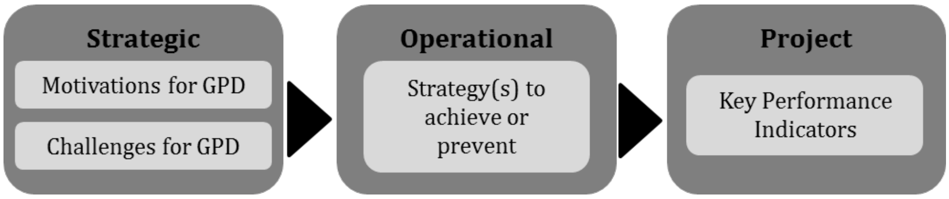

Figure 3-3 Main themes developed in the coding scheme for the exploratory study

3.6 Study two: Multiple case studies

Two in-depth case studies with multiple methods for data collection, including interviews, observations and documents analysis, were conducted in study two to address the research objectives at the descriptive study I stage (see Table 3-2). First, issues surrounding these methods are discussed in general before introducing the two case studies and the specific use of the research methods in this study. Parts of the study can be referred to in paper IV and VI (Appendix 5).

A case study typically uses multiple methods for data collection by a direct observer(s) in a single, natural setting that considers temporal and contextual aspects of the contemporary phenomenon under study, without experimental controls [Meredith, 1998]. When conducted in an industry environment, it allows for in-depth identification of a variety of contextual factors when the phenomenon studied is dependent on a large number of factors [Verschuren & Doorewaard, 2010], which may be too complex to gain understanding with a survey for example [Yin, 2009]. However, such studies may result in large amounts of information and may reveal results that were not predicted at the start [Ahmed-Kristensen, 2007]. Furthermore, gaining access to industrial participants at a company for a research study can be time consuming. Despite this, case studies carried out in an industrial environment, rather than with students in the laboratory for example, provide in-depth understanding of real time tasks and activities that lead to creative insights of high validity for practitioners [Voss *et al.,* 2002, Ahmed-Kristensen, 2007].

Case studies are typically used in order to understand the 'How' and 'Why' research questions of a given phenomenon [Yin, 2009]. Ensuring that the research questions are addressed relies upon the ability to generalise the results that extend beyond the specific case [Ahmed-Kristensen, 2007]. This can be achieved with the investigation of multiple case studies [Eisenhardt, 1989]. Furthermore, triangulation increases the reliability and validity of results in case studies and includes the use of multiple data collection methods such as protocol analysis, interviews, archival records, documentation or observations. For this study, interviews, observations and document analysis were the primary source for data collection during the multiple case studies and the issues surrounding these are briefly discussed in the following paragraphs.

Interviews can be used to capture data about more than one case and are retrospective in nature [Ahmed-Kristensen, 2007]. They rely on the recollection of participants, who may have a biased view. To limit such bias, questions can be prepared in advance, although additional questions may need to be introduced in response to the interviewee where necessary. In general, interviews can be classified within three different types: structured, semi-structured and open-ended interviews and are characterised by the amount of freedom given to the interviewee [Kvale, 1996].

Observations are undertaken in real-time and if carried out in their natural environment; they can provide the in-depth understanding required to capture the sequential context of events [Voss *et al.,* 2002, Yin, 2009]. Issues related to participant bias, common with retrospective methods such as interviews or surveys, can be avoided with observations that capture data in real-time [Ahmed-Kristensen, 2007]. There are two types of observational studies: direct observations - the researcher does not participate in the work completed by the team or individual observed; and participant observations – the researcher actively participates in the work completed by the team or individual. Observational studies may focus on small slices of time in the design process such as Badke-Schaub and Frankenberger analysis of design projects [1999] or longer studies observing the entire process such as Hales study of an engineering design project [1987].

Document analysis may involve the analysis of documents that are part of the company or the researchers' work practice, i.e. are created independently from the research study or specifically created for the research study [Ahmed-Kristensen, 2007]. If the documents analysed are part of the company and not created specifically for research purposes, then the disturbance to the company due to the research is minimal. Documents can be related to the process and/ or product and may include reports, detailed project plans, electronic documentation, etc.

In sum, document analysis and interviews can be useful if the aims include obtaining knowledge across cases, whereas observational methods provide a deeper, but often shorter, insight into a process.

3.6.1. Multiple case studies: Company background

The companies were selected from a previously established interest group including 65 companies; characterised by their high involvement with GPD activities and their interests in developing tools to manage such collaborations. The criteria for selection were based on the fulfilment of the research aims and practicality and included:

- The company should be a large Danish manufacturing company with their headquarters in Denmark
- Parts of the company's PD process have been offshored to a low cost country e.g. China, India, Poland
- The company's global R&D facility should be involved with development tasks and activities during the PD process.

Based on these criteria, two large Danish manufacturing companies with globally distributed R&D facilities were selected and are briefly introduced here. Key characteristics of the companies are outlined in Table 3-7 and can be referred to in more detail in paper VI.

3.6.1.1. Company A

The company is considered a world leader within the area of refrigeration, water controls and motion heating. For the purpose of this study, research was conducted within the automatic controls division, which specialise in the production of large industrial valves and controls for the refrigeration and air conditioning markets. The products are complex and include a large number of sub-systems and components, which are developed, produced and sold worldwide. In 2011, the company established an offshore R&D facility in India with the following key motivations: To reduce costs by gaining access to low labour costs of skilled engineers in India, and to increase flexibility by utilising additional resources provided by Indian engineers to free up the time of the

Danish engineers; enabling the Danish engineers to work on more complex tasks. Since the collaboration began, less complex tasks such as the conversion of old product drawings to a digital form were distributed to the R&D facility in India. The collaboration between the Danish and Indian R&D facilities form the basis for the research conducted in this case study.

3.6.1.2. Company B

The company specialise in the development and manufacture of blood analysis instruments, such as blood gas analysers and syringes for the pharmaceutical industry. They are considered pioneers in blood gas testing, introducing the world's first commercially available blood gas analyser. The company operates globally with R&D and production facilities in Denmark, USA and Switzerland and have recently established offshore R&D facilities in China and Poland with the motivation to reduce costs by gaining access to skilled engineers in low cost regions. From early in the collaborations, the Danish R&D were interested in providing the engineers at the global R&D facilities with a high level of responsibility toward development tasks. Collaborations between the offshored R&D facilities in China and Poland with the R&D facility in Denmark form the basis for the research conducted in this case study.

Company characteristics	**Company A**	**Company B**	
Headquarters based in:	Denmark	Denmark	
Industry sector:	Refrigeration & air conditioning	Pharmaceutical	
No. of employees:	24,000 employees global	2,700 employees global	
Turnover:	34 billion DKK (in 2012)	3,4 billion DKK (in 2010)	
Offshored R&D facilities involved in study:	India	China	Poland
No. years offshored R&D established at study time:	2.5	1.5	0.8

Table 3-7 Key characteristics of Company A and Company B

3.6.2. Description of multiple case studies

The aim of this study was to gain an understanding of how KPIs are used to monitor factors influencing the success in GPD projects, primarily addressing research question 2 and partially question 1 in section 3.2. The specific objectives of the study were:

a) To elucidate the current practice for selecting KPIs in GPD.
b) To investigate how KPIs monitor both the negative and positive impacts in GPD at a project-level.
c) To identify the key factors influencing success in GPD at a project-level.

Based on these objectives and the knowledge gained from the exploratory study, multiple case studies in industry were considered the most appropriate approach as they allow for more in-depth understanding of a variety of contextual factors in their natural environment, as opposed to surveys for example. Furthermore, multiple case studies were preferred, rather than a single case study, to improve the generalisability of results. To strengthen the results of case study research and to fully investigate the aims in study two, multiple methods of data collection were carried out for each case study, allowing for the triangulation of results. The data collection methods included a total of 23 semi-structured interviews, 34 direct observations during meetings and the analysis of company documentation. The characteristics of the data collection methods for Company A and Company B are summarised in Table 3-8, Table 3-9 and Table 3-10 and can also be referred to in section 3.4. The specific use of these methods in study two is presented separately according to Company A and Company B in the following sections.

- First, the experimental setup of the research methods employed and the participants at Company A are discussed in more detail in sections 3.6.3 and 3.6.4 respectively.
- Second, the experimental setup of the research methods employed and the participants at Company B are discussed in more detail in sections 3.6.5 and 3.6.6 respectively.

The two companies are discussed together in relation to the limitation of the research methods and analysis method in sections 3.6.7 and 3.6.8 respectively.

Interviews:	**Company A**	**Company B**
No. of interviewees	12 (8 x Danish engineers, 4 x Indian engineers)	11 (3 x Danish engineers, 6 x Chinese engineers, 2 x Polish engineers)
Length	45-60 minutes	45-60 minutes
Type	Semi-structured	Semi-structured
Location	3 x Face-to-face (with Danish engineers), 9 x Online (5 with Danish engineers, 4 with Indian engineers)	9 x Face-to-face (3 with Danish engineers, 6 with Chinese engineers), 2 x Online (with Polish engineers)
Audio-recorded	Yes	Yes

Table 3-8 Characteristics of interviews conducted at Company A and Company B

Observations:	Company A	Company B	
Observations of *	Real GPD project tasks	Real GPD project tasks	Real GPD project tasks
No. of participants	10	14	13
Offshored R&D involved	India	China	Poland
No. of observations	27	3	4
Length	30-90 minutes	approx. 60 minutes	3 x approx. 60 minutes. 1 x 2-day workshop
Type	Direct	Direct	Direct
Location	Online	Online	3 x Online, 1 x Face-to-face
Time period of observations	8 months	1 month	3 months
Audio and video recorded	15 observations	No	No

**Note: Two GPD projects were observed at Company B*

Table 3-9 Characteristics of observations conducted at Company A and Company B

Documentation:	Company A	Company B
Company	Organisational charts, standard PD process, product portfolio charts, project management work procedures.	
Project	Project plans, risk assessments, project metrics, meeting minutes, project drawings.	

Table 3-10 Characteristics of documents collected at Company A and Company B

3.6.3. Multiple case studies: Experimental setup at Company A

The experimental setup of the interviews, observations and collection of documentation at Company A are presented in more detail here for study two and can be referred to in paper IV.

3.6.3.1. Experimental setup of interviews

The interviews aimed to develop an understanding toward the influence that globalising parts of PD has on success at the project-level and to elucidate the current practice for selecting KPIs, addressing objectives (a) and (c) in study two. In addition, the interviews provided background understanding in relation to the global collaboration under investigation and standard procedures used at the company and were used to capture data retrospectively. Semi-structured interviews were conducted to provide the interviewee with the opportunity to expand on answers and provide the researcher with room to ask additional questions where necessary to fulfil the aims of the study. First, the interviewees were asked to describe how the collaboration with the offshored R&D facility in India had impacted the team in Denmark (and vice versa) and second, they were asked to describe the current practice for the selection of KPIs for measuring performance in GPD projects. In addition to interview questions, a modular interview guide was developed to enable the interviewer to switch between interesting topics dependent on the knowledge of the interviewee. The interview preparation and main interview questions can be referred to in Appendix 3. Considerations toward how to structure an interview guide, keep records, and create transcripts was followed in accordance with recommendations by Yin [2009]. The interviews lasted between 45 – 60 minutes and the participants were interviewed in their own environment. An online meeting platform was used when it was not possible to conduct interviews face-to-face. All interviewees were interviewed individually and audio-recorded. Permission was asked from the participants prior to audio-recording and none of the participants declined.

3.6.3.2. Experimental setup of observations

The observations aimed to gain a deep insight towards the application of KPIs and how the KPIs monitor the challenges and motivations in GPD projects, addressing objective (b) in study two. Furthermore, the observations provided the in-depth understanding to investigate the cause-effect relationships of factors influencing success at a project-level, addressing objective (c) in study two. Direct observations were conducted i.e. the researcher did not actively participate in the work under study. Observations of real tasks and activities during a GPD project, involving engineers from the Danish and Indian R&D, were conducted as opposed to activities specifically created for a research project. Over the duration of the GPD project, 27 project meetings that lasted between 30 – 90 minutes over a time period of 8 months were observed. The project meetings were held with the online meeting platform to accommodate the globally dispersed project team. 15 of the meetings were audio and video recorded. Technical difficulties at the company prevented the remaining meetings from being recorded. The background of the observed GPD project is presented here and key characteristics of the project are illustrated in Table 3-11.

Since the collaboration began, the Danish engineers experienced difficulties with the Indian engineers and a number of tasks and activities were neither completed on time nor to the desired quality. The motivation of the Indian engineers towards the tasks, which were routine in nature see Chapter 3 section 3.6.1.1, was seen as a contributing factor to these difficulties and therefore a lead engineer in Denmark decided to involve the Indian engineers as the ‘main drivers’ in a more complex PD project in order to increase their motivation. The objective of this project was to improve the performance of an existing valve range by increasing the product lifetime. The project was introduced as a 'Pilot' project and the solution was known by the Danish engineers with the primary aim to improve the collaborations, whilst keeping risk low. The project included 10 engineers from the R&D facility in Denmark and India and was expected to last three to four months. The PD process followed during the project (Figure 3-4) was similar to a Stage-Gate model commonly used in manufacturing companies see Chapter 2 section 2.1. Initially, a root cause analysis was conducted by the project team to identify the critical issue with the valve and create a valid business case for the project. Following this, the redesign and development of the product valve was completed before the initial testing of prototypes was finalised, with final designs sent to the production site in China for manufacture.

Figure 3-4 Standard product development process followed for GPD projects at Company A

Key characteristics	**Project I**
Product to be developed	Industrial valve
Expected duration of project	3-4 months
PD stages observed*	P1, P2, P3, P4, P5
Offshored R&D facility involved in project	India
No. of years offshored R&D established at time of study	2.5
Production at global R&D facility	No

**Note: see Figure 3-4 for PD project stages*

Table 3-11 Key characteristics of GPD project observed at Company A

Company and project documentation such as detailed project plans, risk assessments, key project metrics and meeting minutes that formed part of the routine tasks at the company were collected and organised to highlight facts and events during the project and support the aims of the study. Informal conversations with engineers at Company A enhanced the comprehension of project situations and further enriched the contextual understanding.

3.6.4. Multiple case studies: The participants at Company A

The interviewees at Company A included 10 engineers, 1 middle level manager and 1 top level manager. 4 of the interviewees were from the R&D in India and 8 from R&D in Denmark. The interviewees were selected based on their experience with the global collaboration under investigation, i.e. the Danish engineers experience with the Indian engineers and vice versa, and also their involvement with the observed GPD project. 10 of the interviewees also represented the core team that participated in the observed GPD project. The participants from Company A are illustrated in Table 3-12. Interviewees - INA1 and INA2 were not involved in the GPD project. However, they had been heavily involved with collaborations between R&D in Denmark and India since they were established and were therefore included in study two.

Interviewee	Position	Years at company	Nationality	Participant in Project I
INA1	Engineering director	10	Danish	X
INA2	PD process expert	12	Danish	X
INA3	Engineering director	29	Danish	✓
INA4	Mechanical engineer	19	Danish	✓
INA5	Mechanical engineer	3	Danish	✓
INA6	Mechanical engineer	7	Danish	✓
INA7	Mechanical engineer	3	Danish	✓
INA8	Mechanical engineer	26	Danish	✓
INA9	Mechanical engineer	3	Indian	✓
INA10	Program manager	5	Indian	✓
INA11	Mechanical engineer	2	Indian	✓
INA12	Mechanical engineer	0.10	Indian	✓

Table 3-12 Participants from Company A during the multiple case studies

3.6.5. Multiple case studies: Experimental setup at Company B

The experimental setup of the interviews, observations and collection of documentation in Company B are presented in more detail here for study two and can be referred to in paper VI.

3.6.5.1. Experimental setup of interviews

The aim of the interviews for Company B was the same as those presented in section 3.6.3.1 for Company A. Furthermore, the experimental setup was similar as illustrated in Table 3-8 section 3.6.2 to allow for the comparison of results with Company A. The interview preparation and main topics in the interview guide remained the same with only slight adjustments to the interview questions dependent on the interviewee's experience (see Appendix 3 for interview questions for Company B). The participants were interviewed in their own environment. 9 of the interviews were held face-to-face and 2 were held on an online meeting platform when it was not possible to conduct interviews face-to-face. All interviewees were interviewed individually and audio-recorded. Permission was asked from the participants prior to audio-recording and none of the participants declined.

3.6.5.2. *Experimental setup of observations*

The aim of the observations for Company B was the same as those presented in section 3.6.3.2 for Company A. Direct observations were conducted i.e. the researcher did not actively participate in the work under study. Observations of real tasks and activities during two GPD projects were conducted as opposed to activities specifically created for a research project. The background of the observed GPD projects is presented here and key characteristics of the projects are illustrated in Table 3-13.

The first project observed included 14 participants from the Danish and Chinese R&D facilities with the aim to develop a new blood gas analyser that performed at a higher speed than previous analysers, enabling doctors and nurses to retrieve more blood samples in a given time frame. The product to be developed was complex with 15 different modules consisting of 10-20 different parts. However, the Chinese engineers were introduced during the product and process design stage of the project (see Figure 3-5 for the standard PD process followed for GPD projects) and therefore, the main design of the product and key decisions regarding its development were already fixed. This routinised the development tasks, leaving little manoeuvrability for design changes by the Chinese engineers. The PD process followed during the project was similar to a Stage-Gate model commonly used in manufacturing companies see Chapter 2 section 2.1. The expected duration of the project was four years. Given the time constraints of this research project, all stages in Figure 3-5 could not be observed and observations were made during stage 3. However, interviews conducted at Company B with participants in the project enabled the previous project stages to be investigated retrospectively. During the project, 3 project meetings were observed over a time period of 1 month, including participants from the Danish and Chinese R&D facilities. Each of the meetings lasted approx. 60 minutes. The project meetings were held on an online meeting platform to accommodate the globally dispersed project team.

The second project observed included 13 participants from the Danish and Polish R&D facilities with the project aim to redesign a current syringe, making it aspirating rather than venting, which would impact a variety of products in the company’s portfolio. In contrast to the previous project, the Polish engineers were included from the project initiation stage and were heavily involved in key decisions regarding the direction for design and development. Furthermore, the Polish engineers were collocated during critical stages of the project. The project followed the same PD process as the previous project outlined for Company B (Figure 3-5). The expected duration of the project was two years. Given the time constraints of this research project, observations were made during stage 2 and 3 in Figure 3-5. During the project, 4 project meetings were observed over a time period of 3 months, which included participants from the Danish and Polish R&D facilities. 3 of the meetings observed lasted approx. 60 minutes and were held during stage 2 of the project. These meetings were held online to accommodate for the globally dispersed project team. 1 of the meetings observed was a 2 day project workshop that was held at the Danish R&D facility with the Polish R&D collocated during the meeting and was held during stage 2 of the project.

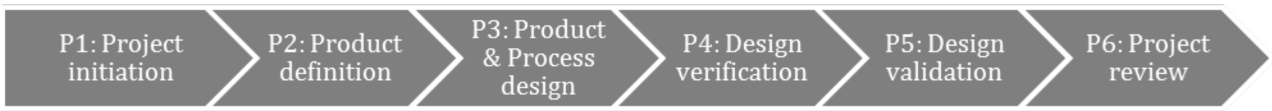

Figure 3-5 Standard product development process followed for GPD projects at Company B

Key characteristics	**Project II**	**Project III**
Product to be developed	Blood gas analyser	Syringe
Expected duration of project	4 years	2 years
PD stages observed*	P3	P2, P3
Offshored R&D facility involved in project	China	Poland
No. of years offshored R&D established at time of study	1.5	0.8
Production at global R&D facility	No	Yes

**Note: see Figure 3-5 for PD project stages*

Table 3-13 Key characteristics of GPD projects observed at Company B

Similar to Company A, project documentation were collected and organised at Company B to highlight facts and events during the observed projects and support the aims of the study. Informal conversations with project managers at Company B enhanced the comprehension of project situations and further enriched the contextual understanding.

3.6.6. Multiple case studies: The participants at Company B

The interviewees at Company B included 8 engineers, 1 middle level manager and 2 top level managers. 3 of the interviewees were from the R&D in Denmark, 6 from R&D in China and 2 from the R&D in Poland. The interviewees were selected based on their experience with the global collaborations under investigation and also their involvement with the observed GPD projects. 9 of the interviewees were also participants during the observations of Project II and 3 were participants during the observations of Project III. It was not possible to collect information regarding the remaining participants involved in Project II and III. The remaining participants involved during the observations were from the Danish R&D facility. The participants from Company B are illustrated in Table 3-14.

Interviewee	**Position**	**Years at company**	**Nationality**	**Participant in:**	
				Project II	**Project III**
INB1	R&D director	4	Danish	✓	✓
INB2	Program manager	2	Danish	✓	X
INB3	Mechanical engineer	4	Danish	✓	X
INB4	Mechanical engineer	1.5	Chinese	✓	X
INB5	Mechanical engineer	1	Chinese	✓	X
INB6	Mechanical engineer	1	Chinese	✓	X
INB7	Mechanical engineer	0.10	Chinese	✓	X
INB8	Mechanical engineer	1	Chinese	✓	X
INB9	Mechanical engineer	1	Chinese	✓	X
INB10	Mechanical engineer	0.7	Polish	X	✓
INB11	R&D director	0.3	Polish	X	✓

Table 3-14 Participants from Company B during the multiple case studies

3.6.7. Limitations of the multiple case studies

Conducting multiple case studies as opposed to single case studies increases the amount of resources required for a study and may result in less depth per case. However, multiple case studies increase the external validity and generalisability of the research and help guard against observer bias [Voss, *et al.*, 2002].

Case studies conducted in their natural setting makes it difficult to control the environment that can otherwise be controlled in a laboratory setting. Despite this, case studies carried out in their natural environment provide in-depth understanding of real time tasks and activities that lead to creative insights of high validity for practitioners [Voss *et al.*, 2002, Ahmed-Kristensen, 2007].

Interviews are retrospective and hence rely on the recollection of the participants and data collected is restricted by what the interviewee is able to articulate [Ahmed-Kristensen, 2007]. Furthermore, leading questions from the interviewer and the tone of voice used may influence the answers provided by the interviewee [Yin, 2009]. To limit interviewer bias, questions were prepared in advance with the freedom to ask additional questions in response to the interviewee’s answers. The same interviewer conducted all interviews.

All interviews during study two were conducted and transcribed in English. Given the different nationalities involved in study two and the participants' proficiency level in speaking English, answers provided to the questions by the interviewees may have, on occasion, been misunderstood or misinterpreted. However, the working language at both Company A and Company B was English and the participants' level of English was considered sufficient. Furthermore, all interviews were audio-recorded, which allowed the researcher to re-visit the interviews for further clarification. This approach was preferred as opposed to involving an interpreter as this can add further complications and misunderstandings as illustrated in studies by Xian [2008] and Ciuk and James [2014].

Given the time constraints of the research project, it was not possible to make the same number of observations at Company B in comparison to Company A. Furthermore, the type of design task and the stage of the GPD project were determined by the companies. Therefore, observations at Company B were not made during all stages of the GPD projects as the projects had already commenced at the time of research. However, the interviews conducted with participants involved with the projects enabled the previous stages of the projects to be investigated retrospectively at Company B.

During observations, participants may try and be *good* by trying to produce the data that they think is desired from them [Ahmed-Kristensen, 2001]. The effect of being observed may have influenced the behaviour of the participants. In Company A, observations were made online during project meetings with minimal disturbance toward their activities. However at Company B, the observations were primarily conducted on-site at the company, at both the Chinese and Danish R&D facilities. The physical presence of the researcher may have disturbed the participants during the GPD projects. In addition, the time and travel expenses increased when the researcher was physically present during the observations at Company B in comparison to Company A. This is discussed further in Chapter 3 section 3.8.

Direct observations carried out in their natural setting allow for an in-depth understanding of the contextual environment. However, this may result in large amounts of data being collected that does not relate to the specific aims of the study. This is also emphasised in Hales's study of an engineering design project [1987] where it is claimed that designers carry out many activities that are not seen as core design activities. To reduce the amount of data collected, field notes were summarised after each observation and structured according to the aims of the study. This is further described in the following section.

3.6.8. Multiple case studies: Analysis method

Data collected from the interviews and observations in Company A and Company B were analysed independently. Based on key themes of the coding scheme developed for study one see Chapter 3 section 3.5.7, a coding scheme for categorising the data collected in study two was developed and redefined as the study progressed based on the ongoing analysis and reflection of data collected (see Table 3-15 for coding scheme developed for the analysis of data for the multiple case studies).

3.6.8.1. The interviews

The semi-structured interviews were audio-recorded and transcribed, which allowed for the transcripts to be revisited and reanalysed as the research project progressed. A pre-defined coding scheme was developed based on the key themes and subsequent codes generated as a result of the literature review and study one see Chapter 3 section 3.5.7. However, as research toward performance measurement in GPD is relatively underdeveloped, themes and subsequent codes in the coding scheme were developed based on key patterns emerging from the empirical study, so as to avoid the confinement of data.

Answers to the specific questions in the interview transcriptions were analysed, a few lines at a time, and categorised according to themes. For example, if the interviewee expressed a challenge with the collaborations this would be categorised within the theme *Challenges with GPD*. Within these themes, sections of the transcripts were analysed and sub-codes to the themes were created in order to identify interesting patterns within the themes. For example, if the interviewee expressed difficulties in relation to understanding company documentation, the category *Documentation* was created as a sub-code for *Challenges with GPD*. The categorisation of the transcripts within themes and sub-codes was an iterative process. Additional themes and sub-codes were created based on new insights from Company A and Company B as the study progressed. Table 3-15 presents the main themes, the sub-codes and the definition (refer to Appendix 3 for an example of a section of transcript that has been categorised). The method for analysis draws on key aspects recommended by Braun and Clarke [2006], where transcripts are iteratively analysed to identify patterns in the data by reading, summarising and coding results multiple times to create convergence around key themes relative to the research aims.

The sub-codes were counted for frequency of occurrence to identify key patterns and relationships within the data. Following the frequency counts, the qualitative analysis of the patterns indicated provided an understanding of the rationale and theory underlying relationships. The analysis of the coded data is comparable to approaches adopted by Mintzberg and McHugh [1985] and Eisenhardt [1989] where qualitative data was supplemented by frequency counts of code occurrence.

3.6.8.2. The observations

Field notes were kept during the direct observations for each of the observed meetings by the researcher as time constraints of the research project and the lack of opportunity to record all of the observed meetings meant they could not be transcribed (see Appendix 3 for structure of the field notes taken). To reduce ambiguity, the field notes were summarised directly after the meetings took place. Areas of uncertainty, such as when participants used terminology specific to the company, were clarified during a telephone conversation with the direct contact person at the company after the meeting. The analysis of the observations followed a similar method to the interviews where the field notes were read, summarised and categorised multiple times to create convergence around key themes relative to the research aims. The main themes created during the analysis of interview transcripts were used as a foundation for the categorisation process of the field notes during the observations. However, additional themes and sub-codes were created as new insights emerged during the observations to avoid the confinement of data (see Table 3-15 for list of codes used during the analysis of observations). For example, the in-depth contextual understanding during the observations enabled selected KPIs to be categorised according to if they were leading or lagging indicators and therefore, *leading* and *lagging* indicators were created as a sub-code for the theme *Performance measurement.* Furthermore, observations provide the environment to identify the sequential relationship of events and as such, relationships between KPIs used in the GPD projects with key challenges and motivations for GPD could be analysed.

Themes	Sub-codes	Definition	Source	Exploratory study: Survey I	Exploratory study: Survey II	Multiple case studies: Interviews	Multiple case studies: Observations
Company	Company A	The identity of the company involved in the study.	n/a	n/a	n/a	✓	✓
	Company B		n/a	n/a	n/a	✓	✓
Interviewee	Danish engineer	The identity of the interviewee involved in the study.	n/a	n/a	n/a	✓	✓
	Indian engineer		n/a	n/a	n/a	✓	✓
	Chinese engineer		n/a	n/a	n/a	✓	✓
	Polish engineer		n/a	n/a	n/a	✓	✓
Motivation for GPD	Cost reductions	To access low labour costs and materials in low cost regions.	Christodoulou *et al.*, [2007]	✓	✓	✓	✓
	Access to new resources	To increase access to global competencies and engineering expertise.	Hansen *et al.*, [2011]	✓	✓	X	X
	Increase customer base	To have design resources closer to local markets, providing increased knowledge of customer needs.	Statistics Denmark [2008]	✓	✓	X	X
	Reduce time to market	To be closer to local suppliers and global markets.	Hansen & Ahmed-Kristensen [2012]	✓	✓	X	X
	Risk mitigation	To share risk during development of new products with global partners.	Christodoulou *et al.*, [2007]	X	✓	X	X
	Flexibility & scalability	To utilise additional resources at global R&D to free up the time of Danish R&D to work on more complex tasks.	Emerged from the data set	✓	✓	✓	✓
Challenge with GPD	Cultural differences	Issues within the team due to cultural misunderstandings.	Hansen & Ahmed-Kristensen [2011]	X	✓	✓	✓
	Communication	Difficulties with communication between the Danish and global R&D.	[Hansen & Ahmed-Kristensen, 2011]	X	✓	✓	✓
	Documentation	Issues related to poor documentation at the company.	Barthelemy [2003]	X	✓	✓	✓
	Lack of common vision	A misalignment between project expectations and work direction.	Emerged from the data set	X	✓	✓	✓

	Knowledge sharing	The availability and accessibility of information at the global R&D facility.	Emerged from the data set	X	✓	✓	✓
	Standardising tools and processes	The standardisation of company procedures in a common platform accessible to the global R&D facility.	Tripathy & Eppinger [2011]	X	✓	✓	✓
Project-level influence factor	Project management	The workload of the project manager as a result of the global collaborations.	McDonough *et al.*, [1999]	X	X	✓	✓
	Task complexity	The complexity of the tasks and activities of the global R&D teams in relation to the product to be developed.	Edmondson & Nembhard [2009]	X	X	✓	✓
	Alignment of interests	The cohesiveness of the completed tasks and activities between global and local R&D teams.	Emerged from the data set	X	X	X	✓
Management approach	Project governance	The level of control applied in the project in order to mitigate the risk of project failure.	Emerged from the data set	X	X	✓	✓
	Modularisation of the product	The separation of the product into modules to allow for the segregation of work packages within the global R&D team.	Tripathy & Eppinger [2011]	X	X	✓	✓
	Modularity of the PD process	The separation of the PD process into tasks and activities that could be distributed globally and worked on autonomously.	Hansen & Ahmed-Kristensen [2012]	X	X	✓	✓
Effect on GPD	Time delays	Time delays as a result of the collaboration.	Emerged from the data set	X	X	✓	✓
	Cost increases	An increase in PD costs as a result of the collaboration.	Emerged from the data set	X	X	✓	✓
	Quality issues	Reductions in the quality of work as a result of the collaboration.	Emerged from the data set	X	X	✓	✓
Performance measurement	Key performance indicator	A quantifiable indicator to measure the success of critical factors.	Gries & Restrepo [2011]	✓	✓	✓	✓
	Leading indicator	Indicators that measure factors impacting a process and are drivers of performance.	Kaplan & Norton [1996]	X	X	X	✓
	Lagging indicator	Indicators that measure output of past activity and typically consist of financial indicators.	Kaplan & Norton [1996]	X	X	X	✓

Table 3-15 The coding scheme used in the exploratory study and multiple case studies

3.7 Study three: Evaluation of support method

A case study with multiple methods for data collection including a workshop, surveys and interviews were conducted in study three to evaluate the impact of a method of support that was developed during this research project. The method of support was developed in the prescriptive stage of the research project based on the results of the two studies carried out at the descriptive study I stage (see section 3.5 and 3.6). The development of the method of support is presented in Chapter 5 and the research methods employed for the evaluation of the support method are presented in the following sections.

Study three addresses the following research objectives at the descriptive study II stage:

a) Evaluate how the proposed method supports the selection of both leading and lagging KPIs in GPD.
b) Evaluate how the proposed method supports the early identification of critical factors influencing success in GPD projects and supports to minimise the risk towards these.

The following sections introduce the company and the specific use of the research methods employed in study three for the evaluation of the support method. Parts of the study can be referred to in paper VII (Appendix 5).

3.7.1. Evaluation of support method: Company background

The company was selected based on the interest shown towards implementing the support method during an industrial workshop held as part of this research project, which focussed on tools to support GPD. The company is briefly introduced here.

The company is a large Danish manufacturing company that specialise in the development and production of ventilation and air handling systems in the marine and offshore sector. Their products include heating, ventilation, air-conditioning and refrigeration solutions for large offshore marine applications, which are marketed and distributed worldwide. The company's headquarters are situated in Denmark with R&D and production facilities also located in China (see Table 3-16 for the key characteristics for Company C).

Company characteristics	Company C
Headquarters based in:	Denmark
Industry sector:	Marine & offshore
No. of employees:	420 employees global
Turnover:	807 million DKK (in 2014)

Table 3-16 Key characteristics for Company C

3.7.2. Description of evaluation of support method

Based on the objectives for the descriptive study II stage, a case study in industry was considered the most appropriate approach for evaluating the impact of the support method to ensure the method could be evaluated in accordance with real tasks and activities in an industry setting. Various research methods were employed for the implementation and evaluation of the support method at Company C, which are described in more detail in the following section and included the following:

- For the implementation of the support method, a four hour workshop facilitated by the researchers in this research project was conducted at Company C during the early planning stages of a development project and included six key members from the Danish R&D facility.

- For the evaluation of the support method, two surveys were conducted with the six participants at the workshop before and after the implementation of the method. Furthermore, semi-structured interviews with two participants from the workshop were conducted five months after the workshop had been completed to allow time for implementation of the support method and to evaluate the behavioural impact the method had on the participants at the workshop.

3.7.3. Evaluation of support method: Experimental setup

The aim of the workshop was to implement the support method in a GPD project at the company described. The workshop was held at the headquarters of Company C in Denmark and lasted approximately four hours. The main researcher in this research project acted as the primary facilitator during the implementation of the support method at the workshop. Preparations for the workshop by the facilitator can be referred to in Appendix 4. The workshop was not recorded to maintain the confidentiality of Company C.

The aim of the survey and semi-structured interviews was to evaluate the impact of the support method at the company. The following key principles were considered in accordance with

Kirkpatrick's approach as extended by Ahmed-Kristensen [2001] during the design of the survey and interviews for the evaluation of the support method:

1. Reaction: The usefulness and applicability of the toolkit
2. Learning: The increased understanding towards key concepts for performance measurement
3. Results: The difference between KPIs selected before and after the toolkit
4. Validation: The improvements required to the toolkit
5. Behaviour: The impact of the toolkit on everyday tasks and activities.

The two surveys completed both before and after the completion of the workshop by participants can be referred to in Appendix 4. The semi-structured interviews were conducted via telephone and lasted approximately 15 minutes and were audio recorded for future reference. The interview questions focussed on the behavioural aspect of the evaluation of the support method, i.e. participants were asked how the method had impacted their everyday tasks and activities since its implementation (refer to Appendix 4 for specific interview questions).

It was not possible to implement the support method in a GPD project given the advanced stage of development of current GPD projects at Company C. However, the Company were interested in implementing the method to support the selection of KPIs in a software development project, which aimed to develop a common platform for conducting and documenting future PD projects at the company. Despite being a software development project, the project was expected to follow the standard PD process employed at the company from the early planning and conceptualisation through to the final testing and evaluation of the software. The participants during study three are presented in the following section.

3.7.4. Evaluation of support method: The participants

The participants in study three are illustrated in Table 3-17 with indication towards their participation during the workshop, surveys and interviews. The participants included six key members from the project team from the R&D facility in Denmark at Company C and ranged from top to middle level management.

Participant	Position	Years at company	Workshop	Surveys	Interviews
INC1	R&D director	35	✓	✓	X
INC2	Sales director	12	✓	✓	X
INC3	Global product manager	30	✓	✓	X
INC4	Program manager	7	✓	✓	✓
INC5	Technical manager	13	✓	✓	✓
INC6	Product manager	15	✓	✓	X

Table 3-17 Participants in Study three: Evaluation of support method

3.7.5. Limitations of the evaluation of support method

The support method was implemented and evaluated in a software development project at a Danish manufacturing company where the main project team was collocated and hence, the results from the evaluation, which are presented in Chapter 5 section 5.4, are valid in this context. Future studies to evaluate the support method in the context of GPD are outlined in Chapter 6 section 6.4.

Due to the time restrictions of the research project and the project being delayed at Company C, the experimental setup described did not provide the necessary environment to evaluate whether the selected KPIs, as a result of the support method, improved the long-term performance of the development project and supported decision making along the process. However, the objectives of the prescriptive study (see Table 3-2) were to develop a method to support the identification of key factors influencing success in GPD and provide a structured approach for the selection and documentation of KPIs to monitor and measure these and therefore, the evaluation focussed on the process for selecting KPIs rather than evaluating the long-term impact on performance.

3.8 Conclusion

Three empirical studies with multiple research methods were employed during this research project. The research approach developed as the project progressed. The direction of the studies and methods of analysis were determined by the data. Each research approach had its limitations.

Study one: Exploratory study provided initial understanding towards the key motivations and challenges for GPD projects and KPIs used for measuring performance and hence, enabled the investigation of the applicability of KPIs in the context of GPD. However, data collected from the two surveys did not provide the rich understanding required to fully investigate the aims in this research project and were primarily used to guide the direction for the subsequent studies.

Study two: Multiple case studies provided an in-depth understanding towards the selection and application of KPIs in GPD at the project-level. In addition, factors influencing the success of GPD were investigated.

The interviews provided initial understanding towards the influence that globalising parts of PD has on success at the project-level and the current practice for selecting KPIs. Furthermore, they provided background information in relation to the global collaborations and enabled GPD projects at the company cases to be investigated retrospectively. However, the interviews did not provide the in-depth understanding to fully investigate the selection and application of KPIs in GPD projects. Hence, direct observations of GPD projects at the two company cases were conducted to provide this understanding. Furthermore, the observations provided the environment to investigate the cause-effect relationships of factors influencing success at a project-level. In addition to triangulating results from the multiple cases studies, the documents collected provided supporting information toward company and project procedures and highlighted key events during the studies.

Based on results from the two empirical studies carried out in the descriptive study I stage, a method of support was developed in the prescriptive stage of this project. The development of the support is presented in Chapter 5.

Study three: Evaluation of the support method provided initial understanding towards the impact the proposed support method had during a real project situation in industry. The proposed support method was evaluated in relation to the verification for supporting: the selection and documentation of both leading and lagging KPIs in GPD; and the early identification of critical factors influencing success in GPD projects and the development of precautionary strategies to minimise the risk towards these.

The research methods employed in study two were time consuming in relation to study one and study three. Given the global nature of the research project, many of the interviews were conducted online to avoid additional travel time and expenses. However, 12 interviews were conducted face-to-face: 6 at the R&D facility in Denmark at Company A and Company B; and 6 at the R&D facility in China at Company B (see Table 3-8), which increased the amount of time spent on travelling. Furthermore, planning the observations in study two was difficult due to the different project time-scales at the two companies. In general, gaining access to industrial participants for study two was time consuming and the different time-zones, due to the global nature of the study, further added to these difficulties. Despite this, data collected in study two provided the richness to fully investigate the aims in this research project.

The total time spent on data collection during the three empirical studies amounted to 1088 hours or 136 days (see Table 3-18). The additional time spent on collecting data for each of the research methods employed during the three studies is useful to assess the effectiveness and efficiency of the research method. The additional time can be considered overhead and was used for: travelling to meetings to arrange the data collection; identifying and setting up company cases; setting up the research instruments; collecting the data; transcribing the interview data; developing a method for analysis; and analysing the data. Survey I required an additional 8 hours; Survey II required an additional 7 hours; each hour of interview data required an additional 22 hours; each hour of observation required an additional 6 hours; and each hour of document analysis required an additional 5 hours. The interviews were the most time consuming of the research methods employed and the document analysis the least. The observations were considered the most efficient and effective research method for this research based upon: the in-depth description achieved towards the research aims of this project: and the low additional time required for data collection, in comparison to the interviews for example.

Time spent on data collection		Time in hours
Study one:	Survey I	80 (10 days)
	Survey II	56 (7 days)
	Total time for study one	136 (17 days)
Study two:	Interviews	520 (65 days)
	Observations	336 (42 days)
	Document analysis	40 (5 days)
	Total time for study two	896 (112 day)
Study three:	Workshop	32 (4 days)
	Surveys	16 (2 days)
	Interviews	8 (1 day)
	Total time for study three	56 (7 days)
	Total time for descriptive study I	1088 (136 days)

Table 3-18 Time spent on data collection during the descriptive study I stage

The method of analysis, in particular, the generation of the coding scheme for the two studies involved a certain amount of subjectivity. The findings from the studies (presented in Chapter 4) were useful to validate the categories in the coding scheme. If the same activity, and therefore the same category, was observed in more than one study, the category was assumed to be valid. A further validation of the coding scheme was carried out by presenting the findings to the two companies that participated during the multiple case studies and is described in more detail in Chapter 5 section 5.2. An evaluation of the proposed method of support based upon the findings was also useful to validate the categories in the coding scheme (described in Chapter 5 section 5.4).

The research methods together provided an insight toward the current practice of performance measurement in GPD at the project-level. The results from study one and two are presented in Chapter 4 and the results from study three are presented in Chapter 5.

Chapter 4 Results

This chapter presents a summary of the key findings at the descriptive study I stage of this research project and their contribution to the research questions and objectives in this thesis.

Firstly, an overview of the key findings in the seven papers written during this research project is presented. Secondly, the findings are presented according to the two studies conducted at the descriptive study I stage of this research project. Finally, the findings from the two studies are discussed with relevant literature and the key implications for industrial and academic communities are highlighted.

The two studies conducted at the descriptive study I stage were: Study one: Exploratory study; and Study two: Multiple case studies. Study one is presented in papers I – III and Study two in papers IV – VII (refer to Appendix 5 for the seven papers). The research methodology employed during the studies was discussed in Chapter 3. The knowledge gained from study one influenced the direction of study two and hence, can be considered a data-driven approach. The multiple research methods employed in the two studies provided different levels of understanding in relation to the research questions and objectives and hence, contribute to different stages of the research project, which was discussed in Chapter 3 section 3.8, and is further discussed in the following sections in Chapter 4.

Results from the third study conducted at the descriptive study II stage of this research project are presented in Chapter 5.

The seven papers written in this research project are presented in Table 4-1 according to: the stages of the DRM they contribute to; and the key area(s) to which they build knowledge, namely:

- KPIs for GPD
- The KPI selection process
- The project-level influence factors.

The seven papers contribute as a whole, or as excerpts to, the different elements and stages of the project and a summary of the papers can be referred to in Appendix 5.

DRM stage:	Research clarification	Descriptive study I	Prescriptive study I	Descriptive study II
Research questions:	(1) What is the current practice for measuring performance in conventional and global PD projects?	(2) How are KPIs used to monitor factors influencing success in GPD projects?	(3) How to support the selection of KPIs that provide project management with timely feedback on performance?	(4) How does the proposed method support the process of selecting KPIs in GPD projects?
KPIs for GPD	Papers I-II Key motivations, challenges and KPIs in GPD.	Papers III - IV Key challenges and KPI classification within leading and lagging in GPD projects.	Paper IV + VII Requirements and conditions for using KPIs in GPD projects.	
KPI selection process		Papers III - IV Key motivations, challenges and practice for selecting KPIs in GPD.	Paper IV + VII Requirements and conditions for selecting KPIs in GPD projects.	Paper VII Validation of support method to support selection of both leading and lagging KPIs.
Project-level influence factors		Papers V - VI Key factors influencing success and management techniques in GPD projects.	Paper VI + VII Requirements and conditions to identify and prioritise factors influencing success in GPD projects.	Paper VII Validation of support method to support the early identification and prioritisation of key factors influencing success.

Table 4-1 The seven papers written during the research project according to the stages of the DRM and the key areas to which they build knowledge

4.1 Study one: Exploratory study

Two surveys were conducted during the exploratory study including: Survey I, which involved 28 Danish companies; and Survey II, which involved 16 Danish companies. Study one addressed research question one in Table 4-1. The specific objectives of the study were:

a) To identify KPIs used in GPD projects.
b) To investigate how the KPIs cohere with challenges and motivations specific to GPD.

The findings from Study one: Exploratory study contribute to the advancement of knowledge towards the selection of KPIs in PD when engineering teams are globally dispersed, which builds on studies that investigate this in conventional PD that typically consists of local, cross-functional members [Griffin & Page, 1996, O'Donnell & Duffy, 2002]. Furthermore, Survey II identifies KPIs selected as a result of key challenges in comparison to common approaches in literature that identify KPIs that are goal-oriented.

The findings from study one are presented according to the key area(s) to which they build knowledge, namely:

- KPIs for GPD.

The key findings are presented in section 4.1.1 and are discussed in relation to relevant literature in section 4.3.

The findings from the exploratory study can also be referred to in papers I, II and III, with specific references made to these in the following sections where necessary. For the overall description of the exploratory study, the experimental setup and the method of analysis see Chapter 3 section 3.5, or papers I, II and III.

4.1.1. KPIs for GPD

The KPIs selected according to key motivations and challenges are presented in the following sections and can be referred to in paper I, II and III.

4.1.1.1. KPIs for measuring the key motivations in GPD

Figure 4-1 and Figure 4-2 illustrate the frequency counts that key motivations for GPD were stated by participants in Survey I and II. The cumulative percentage of the frequency counts is also illustrated, which is useful for making comparisons across different datasets and for highlighting the most important factors [Wilkinson, 2006]. In Survey I, the key motivations stated by the participants were related to *Cost reductions*, *Access to new resources* and *Flexibility & Scalability*. This is comparable to the motivations stated in Survey II, with the exception of *Reduce time to market*, which was the most frequently stated motivation. In Survey I, *Cost reductions* was the most stated motivation, accounting for 43% of the total frequency counts, which reaffirms previous studies in literature that highlight the opportunity to reduce costs as a key motivation for Danish companies to pursue GPD [Statistics Denmark, 2008]. Although *Cost reductions* was among the most frequently stated motivations in Survey II, the frequency counts were more balanced. The balanced distribution further justifies the importance of the key motivations for GPD highlighted in previous studies [Christodoulou *et al.*, 2007, Hansen & Ahmed-Kristensen, 2012] see Chapter 2 section 2.2.2. Furthermore, 'other' motivations for GPD than those identified in literature were not stated across the two surveys, which indicates that this area of research is beginning to mature.

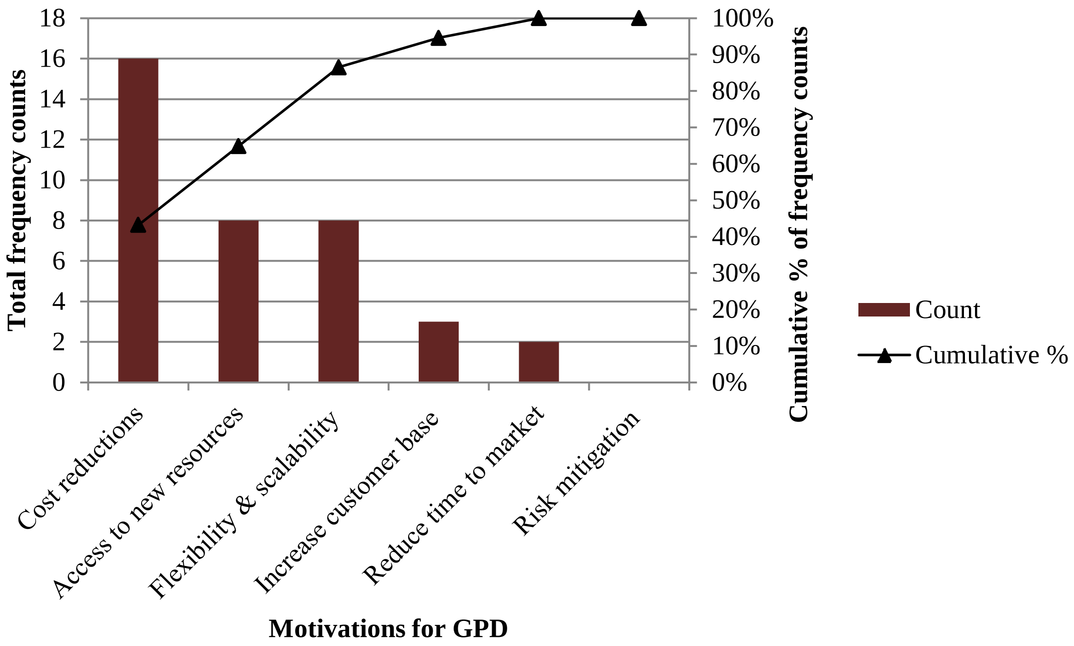

Figure 4-1 Frequency counts of key motivations for GPD stated in Survey I

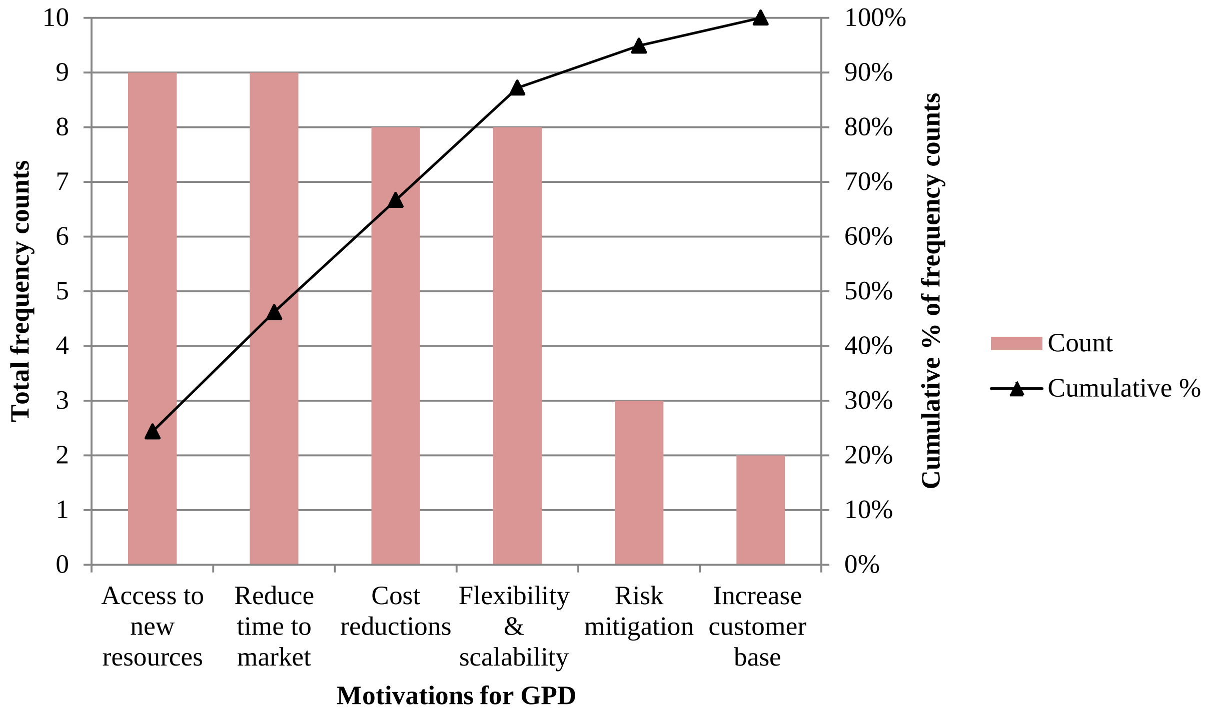

Figure 4-2 Frequency counts of key motivations for GPD stated in Survey II

Table 4-2 illustrates KPIs stated by participants from Survey I and II for measuring the previously stated motivations for GPD in Figure 4-1and Figure 4-2. A total of 17 KPIs across the two surveys were stated for measuring the motivations. The most frequently stated KPIs included: *Development cost*, *Project lead-time* and *Customer satisfaction*, which are also common KPIs used for measuring performance in conventional PD see Chapter 2 section 2.3.3. This implies that KPIs in conventional PD are also applicable in the context of GPD. However, as highlighted in Chapter 2 section 2.3.3 and discussed in papers II and III, KPIs in conventional PD have been described as lagging in nature and measure the outcome of a process rather than factors influencing success along the process and hence, lagging KPIs may not provide the necessary feedback required to avoid challenges in GPD encountered along the process.

There were 4 ‘other’ KPIs stated for measuring the motivations specific for GPD that could not be categorised according to those in conventional PD in Survey II, which implies that additional KPIs to those commonly found in conventional PD may be required for GPD. The ‘other’ KPIs stated, namely: *No. of new alliances; No. of sales from new location*; and *No. of solved work packages* were lagging in nature and focus on measuring the outcome as a result of pursuing GPD. Alternatively, the KPI: *Capability of supplier delivery* focusses on assessing the potential for success before pursuing GPD in relation to the capability of the supplier to perform as expected. Such KPIs have been described as leading in nature [Kaplan & Norton, 1996] and provide predictive feedback in relation to the potential factors that may influence success in GPD along the process and hence, inform management of where along the process precautionary strategies need to be set and is further elaborated on in paper III.

Motivations for GPD	**KPIs**	**Freq. in Survey I**	**Freq. in Survey II**	**Freq. in total**
Access to new resources	Leads to future operations	3	0	3
	Percentage of new product sales	2	0	2
	No. of new projects	0	2	2
	No. of new alliances*	0	2	2
Cost reductions	Break-even time	3	0	3
	Return on Investment	5	1	6
	Margin goals met	2	3	5
	Development cost	12	3	15
	Profit goals met	3	0	3
Reduce time to market	Project lead time	6	8	14
	Project plan status	6	2	8
Flexibility and scalability	Capability of supplier delivery*	0	2	2
	Market position	5	0	5
Increase customer base	Customer satisfaction	10	0	10
	Market share	4	1	5
	No. of sales from new location*	0	1	1
Risk mitigation	No. of solved work packages*	0	1	1

*Note: *'Other' KPIs stated that could not be categorised according to common KPIs in conventional PD.*

Table 4-2 KPIs stated for measuring the key motivations in GPD from Survey I and II

4.1.1.2. KPIs for monitoring the key challenges in GPD

Figure 4-3 illustrates the frequency counts that key challenges in GPD were stated by participants in Survey II. Data regarding the key challenges in GPD were not collected in Survey I. Issues related to *Communication* and *Cultural differences* were the most frequently stated challenges encountered in GPD with counts of 16 and 10 respectively. The high frequency that these challenges were stated signifies the perceived importance of the challenges as factors that influence the success of GPD. The occurrence of such challenges is confirmed in literature where the geographical dispersion of teams often results in cultural misunderstandings and difficulties with communication see Chapter 2 section 2.2.2. 'Other' challenges in GPD to those identified in literature were not stated in Survey II, which indicates that this area of research is beginning to mature.

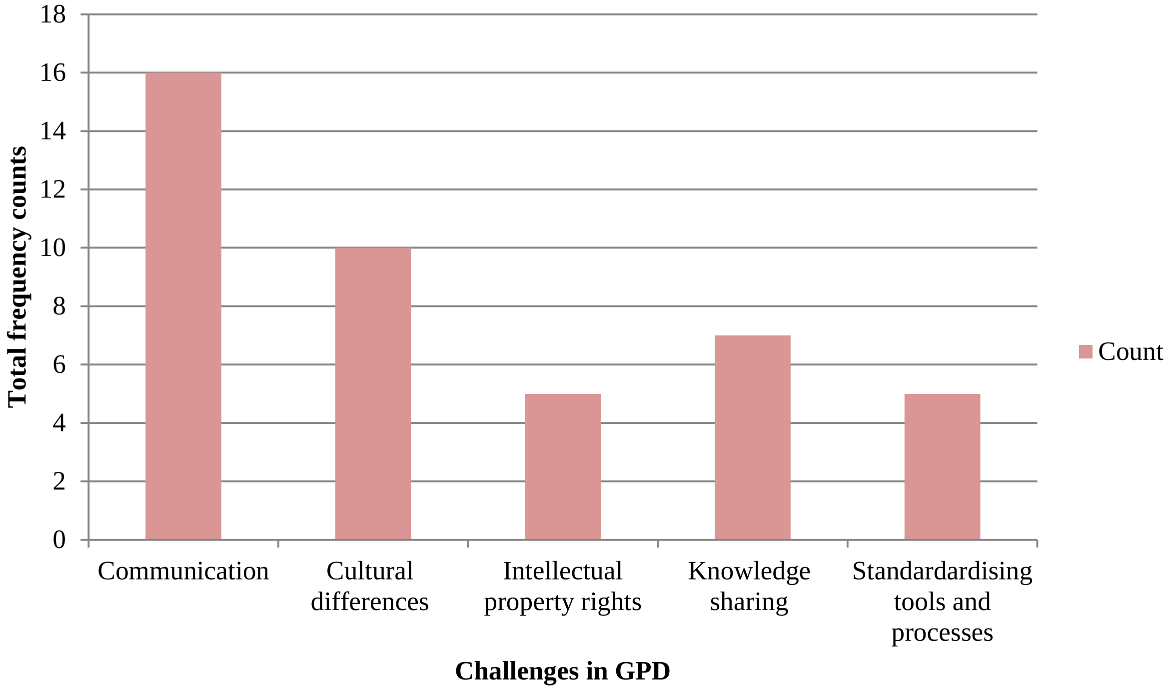

Figure 4-3 Frequency counts of key challenges in GPD stated in Survey II

Table 4-3 illustrates KPIs stated by participants from Survey II for monitoring the previously stated challenges encountered in GPD. A total of 8 KPIs were stated, 2 of which could be categorised according to common KPIs in conventional PD projects and 6 'other' KPIs that could not be categorised. This implies that additional KPIs to those commonly found in conventional PD projects may be required for monitoring the challenges in GPD. The KPIs in Table 4-3 were only stated once by participants, with the exception of *Frequency of process problems*, which was stated twice. However in Survey II, the majority of the answers provided by participants for the KPIs for monitoring the challenges were not considered measurable, such as *Understanding of the situation* as a KPI for monitoring the challenge of *Cultural differences.* This highlights the difficulties experienced by participants when stating KPIs for monitoring the challenges and is further elaborated on in paper II.

The majority of 'other' KPIs stated focussed on the occurrence of problems encountered during GPD in relation to communication, documentation and general process/ project issues. In comparison to many of the KPIs stated for measuring the motivations that focussed on measuring the outcome as a result of pursuing GPD and were lagging in nature, the 'other' KPIs stated for monitoring the challenges focussed on measuring factors that influenced the success of the outcome along the process and were leading in nature such as *Availability of documentation, Frequency of communication problems, Frequency of process problems, etc.* Such KPIs provide predictive feedback in relation to the potential factors that may influence success in GPD and hence, are described as leading KPIs that drive performance, which is highlighted in Chapter 2 section 2.3.1 and is further elaborated on in paper III.

Challenges in GPD	**KPIs**
Communication	No. of project goals met on time No. of agreements kept* No. of problems during project* Frequency of communication problems*
Cultural differences	Employee feedback on job stability*
Intellectual property rights	No. of patents
Knowledge sharing	Availability of documentation*
Standardising tools and processes	Frequency of process problems*

*Note: *'Other' KPIs stated that could not be categorised according to common KPIs in conventional PD.*

Table 4-3 KPIs stated for monitoring the key challenges in GPD from Survey II

4.1.2. Summary

The previous section presented the key findings from study one. The exploratory study addressed research question one in Table 4-1. The specific objectives of the study were:

a) To identify KPIs used in GPD projects.
b) To investigate how the KPIs cohere with challenges and motivations specific to GPD.

In relation to these objectives, the findings presented contribute to the advancement of knowledge towards key motivations and challenges encountered in GPD and KPIs selected for monitoring and measuring these, which has rarely been addressed in the context of GPD in literature.

A more in-depth understanding towards the key motivations and challenges encountered in GPD and the influence these have at a project-level was required. Furthermore, the selection and application of KPIs in GPD, in particular in relation to those selected and used for monitoring the challenges in GPD at the project-level, was required to fully address the aims of this research project.

4.2 Study Two: Multiple case studies

Two case studies with large Danish manufacturing companies with offshore R&D facilities in India, China and Poland were conducted during study two. Study two addressed research question two in Table 4-1. The specific objectives of the study were:

a) To elucidate the current practice for selecting KPIs in GPD.
b) To investigate how KPIs monitor both the negative and positive impacts in GPD at a project-level.
c) To identify the key factors influencing success in GPD at a project-level.

The findings from Study two: Multiple case studies contribute to the advancement of knowledge by providing unique insight towards key cause-effect relationships of the factors influencing the success in GPD, which is seldom addressed in literature with multiple longitudinal case studies in GPD at the project-level, providing the basis for researchers and practitioners to develop practical tools in GPD. Furthermore, the study builds on previous studies in the field of GPD, which highlight the importance of selecting KPIs to support the identification and avoidance of problems as they arise [Christodoulou *et al.*, 2007, Hansen & Ahmed-Kristensen, 2012], by developing an understanding towards the selection and application of KPIs in accordance with key challenges encountered in GPD at the project-level.

The findings from study two are presented according to the key area(s) to which they build knowledge, namely:

- The KPI selection process
- KPIs for GPD
- The project-level influence factors.

The key findings are presented in sections 4.2.1, 4.2.2 and 4.2.3 and are discussed in relation to relevant literature in section 4.3.

The findings from the multiple case studies can also be referred to in papers IV, V, VI and VII, with specific references made to these in the following sections where necessary. For the overall description of the multiple case studies, the experimental setup and the method of analysis see Chapter 3 section 3.6, or papers IV, V, VI and VII.

The different research methods employed during the multiple case studies provided different levels of understanding in relation to the key knowledge areas outlined previously and is further highlighted in the following sections.

4.2.1. The KPI selection process

The process for selecting KPIs at Company A and Company B is presented here and can be referred to in paper VII.

At company A, there was a lack of a structured process for selecting project-level KPIs to measure the performance of GPD as highlighted in the following quotation:

> "*Today we don't have any system… yes we have the KPIs for accounting and cash-flow… and that is deployed down from top level so we are all in the same boat … but there should be some team related KPIs… that covers both teams so we have some common goals.*" Danish engineering director, Company A (INA3 in Table 3-12).

During the observations, it became apparent that the process for selecting KPIs at the project-level was largely influenced by the standard PD process followed at Company A (see Figure 3-4 in Chapter 3 section 3.6.3 for the standard PD process). The tasks undertaken at the business case stage assisted the Danish engineers in setting and documenting KPIs related to budgetary requirements, project schedules, and pre-defined product quality requirements, which were aligned with high level KPIs at the company. However, the global R&D was not included in this selection process.

At Company B, project-level KPIs selected for measuring performance of GPD were to adhere with high level KPIs at the company, which included: project schedule and costs; customer satisfaction; and product quality. To further support the development and documentation of project-level KPIs, Company B employed a KPI selection workshop during the project initiation stage of GPD projects (see Figure 3-5 in Chapter 3 section 3.6.5 for the standard PD process), with the high level KPIs being the starting point for selection. During observations at Company B, the primary approach for selecting project-level KPIs at the KPI selection workshop was a brainstorming session where key members from the Danish R&D were asked to select KPIs they would like to work with for measuring performance, whilst adhering to the high level KPIs at the company. However, there was a lack of experience and understanding of the purpose among the Danish engineers toward selecting and using KPIs and the Danish project manager experienced difficulties with gaining commitment. As a result only a few Danish engineers actively participated in the brainstorming session. The global R&D did not participate during the selection process.

To fully understand the implications of the selection processes described, there was a requirement to observe the application of KPIs in GPD projects at Company A and Company B. This is described in the following section.

4.2.2. KPIs for GPD

The application of KPIs in the three GPD projects and how these monitored key challenges encountered at Company A and Company B is presented here and can be referred to in paper IV and VII.

4.2.2.1. Project-level KPIs in GPD

Table 4-4 illustrates the KPIs selected and used during the observed GPD projects at Company A and Company B, which were grouped according to common performance dimensions typically found in conventional PD. The majority of the KPIs used could be grouped according to these dimensions and can largely be explained given the adherence to the high level KPIs during the process for selecting project-level KPIs outlined previously, which related to: project costs; time schedules; and product quality objectives. The key findings are outlined here and discussed in more detail in the following section.

- The majority of the KPIs used during the projects were financial and focussed on measuring performance in relation to development costs such as *Return on investment, Total project cost, Planned Vs Actual resources,* etc. This further reaffirms studies in literature that highlight the tendency of practitioners in PD to select KPIs that focus on the more tangible outcomes and relate to financial targets [Tatikonda, 2007] see Chapter 2 section 2.3.3.
- KPIs used in each of the observed projects could be grouped according to performance dimensions typically found in conventional PD, which implies that such dimensions are also important in the context of GPD. However, selecting KPIs according to such dimensions alone has been criticised and results in lagging KPIs, which have been described to measure

the outcome of past activity, rather than those that monitor factors influencing success along a process and are leading in nature [Kaplan & Norton, 1996].

- Key challenges encountered during the GPD projects in relation to: a lack of common vision, which was identified during a project risk assessment at Company A; and poor documentation, which was identified during the KPI selection workshop at Company B resulted in the selection of four ‘other’ KPIs in Table 4-4. However, the ‘other’ KPIs were often used as lagging KPIs that provided time-delayed feedback towards key challenges encountered during the projects, which was inadequate to avoid project time delays and design rework.

The use of the KPIs in the observed GPD projects in relation to the key challenges encountered is described in the following sections.

			Company A	Company B	
Performance dimensions	**KPI**	**Definition**	**Project I**	**Project II**	**Project III**
Development Cost	Cost of Product Development.	Estimated resources required for product development.	✓	✓	✓
	Return on investment.	Yearly cost savings after investment.	✓	✓	✓
	Planned Vs Actual resources.	Expected resources used in comparison with actual used.	✓		
	Total project cost.	Estimated resources required for product development.		✓	✓
	Cost of project delay.	Financial implications of project delays.		✓	✓
Development Time	Project lead time.	Amount of time from project initiation to completion.	✓	✓	✓
Product Quality	No. of product lifecycles.	Durability of the product.	✓		
	Customer satisfaction.	Usability of product prototypes.		✓	✓
Other	Documentation errors.	Number of errors found in drawings completed by global R&D.	✓	✓	
	Document approval time.	Time taken to approve documents by internal approval board.			✓
	Internal design expert feedback.	Feedback from design experts at company, external from project.	✓		
	Supplier feedback on assembly.	Inclusion of supplier early in product development.	✓	✓	✓

Table 4-4 KPIs used during the observed GPD projects at Company A and Company B

4.2.2.2. The use of lagging KPIs for monitoring key challenges in GPD projects

A lack of common vision within the GPD teams during the observed projects at Company A and Company B was a key challenge encountered that resulted in design rework and project time delays. The KPIs used to measure performance in the GPD projects (Table 4-4) did not provide the sufficient feedback to avoid the impacts on project success and is further exemplified here.

At Company A, the GPD project was introduced to the Indian R&D as a ‘Pilot’ project with the aim of improving the collaborations with the Danish R&D (see Chapter 3 section 3.6.3.2 for background of Project I). As such, the Indian engineers felt the need to perform to a high standard and invested a large amount of time and resources during the planning stage of the project and proposed a number of solutions, which would potentially add value to the project and impact additional product variants outside of the project. However, these propositions were rejected during a project meeting in the detail design stage of the project as they were considered too ambitious given the solution the Danish R&D had in mind. The project meeting focussed on the evaluation of the proposed solutions against the design specifications to ensure that there was a common vision within the project team in relation to the product to be developed. This involved feedback from a number of design experts from the Danish R&D and hence, the KPI: *Internal design expert feedback* was used as a measure for the common vision. The rejection of the propositions caused confusion amongst the Indian engineers in relation to the project expectations and resulted in design rework, which was a key cause for the project being delayed by two and a half months and is further elaborated on in paper IV and VI.

The risk of a lack of common vision within the project team was identified whilst conducting the standard project risk assessment at the company in the planning stage of the project. This involved identifying the root cause of the risk and reporting the likelihood and influence the risk may have on project success. Despite following this process, the influence that a lack of common vision had on the project in terms of time delays was only identified during the later stages of the project when measuring the lagging KPI: *Internal design expert feedback*. A leading KPI, which have been described to measure factors influencing the success of a process and drive performance [Kaplan & Norton, 1996], was not selected to monitor the influence of the risk throughout the progression of the project, and hence adjustments were only made once the risk had influenced the success of the project in terms of timing.

At Company B, a lack of common vision within the GPD team was encountered during the design development stage in Project II, which resulted in design rework. The main design for the gas analyser was already fixed when the Chinese engineers were introduced, which routinised the development tasks and left little manoeuvrability for design changes by the Chinese engineers (see Chapter 3 section 3.6.5.2 for background of Project II). However, early in the collaborations, the Chinese engineers expressed their desire to work on complex development tasks. This resulted in design re-work as when the Chinese engineers attempted to improve their individual product modules, they discovered that the Danish engineers had already attempted the same improvements unsuccessfully. Such scenario was demotivating for the Chinese engineers as innovative freedom was reduced and is highlighted in the following quotation:

"We joined the project at stage 2, so we don't know the whole background for this product development project and this actually causes some difficulty when we engage in the project… when we start to think of some new things to improve the concept, we will think of a new idea ourselves but if after 2 or 3 weeks later, you would like to show the idea to our team (the Danish R&D), "this is our new idea, I think it's good", they just tell you they have tried that… so this is a waste of time." Chinese mechanical engineer, Company B (INB5 in Table 3-14)

The lack of common vision in the project was not highlighted as a key challenge during the KPI workshop and a leading KPI was not selected to monitor this to provide the necessary feedback to avoid design rework. Involving the global R&D during the KPI workshop may have highlighted this challenge at an early stage with the importance of involving all stakeholders in the selection process highlighted in literature [Neely *et al.,* 2000].

Given the challenges encountered during the observed GPD projects, the KPIs in Table 4-4 did not provide the predictive insight required to setup intervention strategies to avoid the risks encountered and further highlights a need for developing predictive measures [Neely *et al.,* 2005]. This is further elaborated on in papers IV and VII.

4.2.2.3. The use of leading KPIs for monitoring the key challenges in GPD projects

In Project III at Company B, it was identified during the KPI selection workshop that the time taken for project documents to be approved internally at the company was a challenge for the globally dispersed engineers, which could be a key cause for project time delays and hence, influence the success of the project. Given adherence to project schedule was an important high level KPI for project success, the KPI *Documentation approval time* was used as a leading KPI in the project to monitor the challenge and provide indication along the process as to where the necessary adjustments were required to avoid delays as a result of this. In this example, identifying a challenge that could influence the success of the project resulted in the selection of a leading KPI and the importance of selecting such KPIs is further highlighted in the following quote:

"Our focus is not on KPIs that measure an outcome e.g. missed deadlines, rather we want to focus on setting up KPIs that prevent us from missing deadlines, and hence, drive performance." Danish R&D director, Company B (INB1 in Table 3-14).

Identifying key challenges prior to selecting KPIs encourages the selection of KPIs that monitor factors influencing the success of a process and hence, are leading in nature. Leading KPIs focus on the measurement of factors influencing success along the process [Kaplan & Norton, 1996] and provide the necessary feedback for management to implement strategies to avoid risks along the process.

4.2.3. The project-level influence factors

The key factors influencing success at the project-level in GPD at Company A and Company B are presented here and can be referred to in papers V and VI.

4.2.3.1. Key motivations and challenges in GPD

The key motivation for establishing offshore R&D facilities at Company A and Company B was:

- To gain access to skilled engineers in low cost regions, such as India, China and Poland, and hence, reduce the overall costs of PD.

Furthermore, Company A were interested in increasing flexibility by utilising additional resources provided by Indian engineers to free up the time of the Danish engineers; enabling the Danish engineers to work on more complex tasks. However, during early collaborations both companies encountered difficulties with managing the globally dispersed engineering teams with a number of tasks not being completed on time or to the desired quality. The key challenges encountered at Company A and Company B stated during the interviews are illustrated in Figure 4-4 and Figure 4-5 respectively. The challenges are presented according to the frequency they were mentioned during the interviews and the cumulative percentage of the frequency counts to allow for comparison across the two companies. Challenges in relation to *Communication*, *Cultural differences* and *Knowledge sharing* accounted for 71% of the total frequency counts at Company A and 78% at Company B, which were also key challenges for GPD identified in the exploratory study (Figure 4-3) and are consistent with previous studies in literature see Chapter 2 section 2.2.2. The key challenges are outlined here and can be referred to in more detail in paper VI.

- Communication – a lack of clear task specifications provided by the Danish R&D to the global R&D facilities at Company A and Company B resulted in the need for additional information for the global R&D to complete PD tasks and hence, influenced their ability to work autonomously. However, additional information to complete tasks was not easily obtained given the geographical dispersion of the R&D facilities, the different time-zones and the lack of a Danish representative at the global R&D facilities. This resulted in time delays and frustration at the global R&D facilities as they would often be waiting for additional information before they could progress with PD tasks and is exemplified in the following quotation:

"It will take a day for the Danish engineers or even in some cases it has taken a week for them to reply… When we requested for the process to follow for manufacturing the components, we did not have any immediate answer and they did not have any immediate document to share." Indian mechanical engineer, Company A (INA9 in Table 3-12).

- Cultural differences – the low degree of autonomy, which typically characterise the working environments in countries such as China and India, in comparison to the high degree of autonomy, which typically characterise the working environment in Denmark see Chapter 2 section 2.2.1 [Hofstede *et al.*, 2010], resulted in an increased need from the global R&D for clearly defined tasks and work packages. This increased the frequency of communications required when coordinating tasks, in particular at Company A, and resulted in frustration with a number of Danish engineers given the initial motivation of the collaborations was to free up their time and hence, allowing them to work on more complex tasks. This is further highlighted in the following quotations:

"I think what we have experienced is the Indian engineers are very good if they get a very specific task with very clear limits or boarders … they can do this, they do it very good…but often, you have to be very specified, you have to be very clear, you have to bring them very good templates, to have a success." Danish mechanical engineer, Company A (INA8 in Table 3-12).

"The relief you have from moving tasks to India is pretty small, and since we've had very, very hard times defining our tasks and getting good results… most of what I see, most of our colleagues (at the Danish R&D)… they just basically do it by themselves." Danish mechanical engineer, Company A (INA5 in Table 3-12).

- Knowledge sharing – The production sites at Company A and Company B were located at the main company headquarters in Denmark and collocated with the respective Danish R&D

facilities. However, there was no production site located at the global R&D facilities in China and India, which increased their dependency on the Danish engineers for product-related information and hence, resulted in time delays as the global R&D would often be left waiting for such information.

"The problem is that, if you're in Denmark, you can get sufficient information from the other supporting teams: production team, marketing team for example….you can get feedback first hand. But here in China, we need to get the feedback from our leader: the mechanical engineer in Denmark, which can take time." Chinese mechanical engineer, Company B (INB4 in Table 3-14).

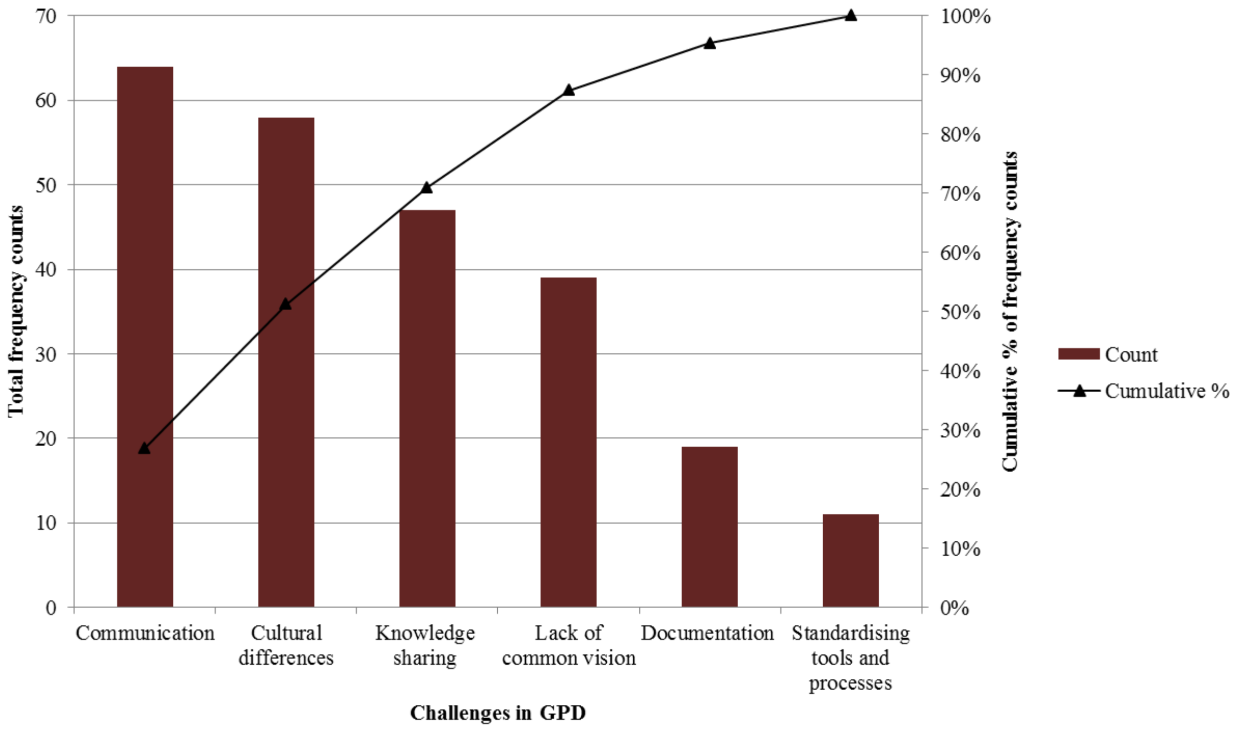

Figure 4-4 Frequency counts of key challenges in GPD stated by interviewees at Company A

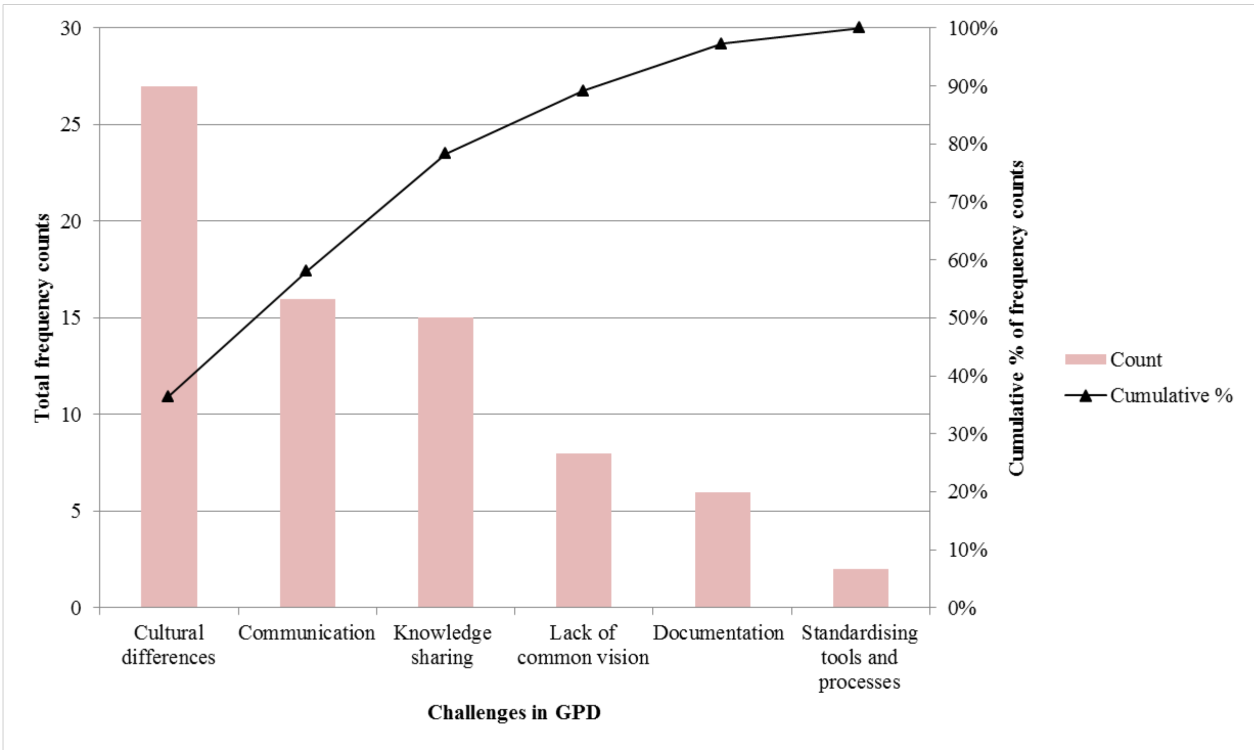

Figure 4-5 Frequency counts of key challenges in GPD stated by interviewees at Company B

The availability of information at Company A and Company B for the global R&D was a central factor that influenced the amount of time spent on coordination activities at the Danish R&D. This was also highlighted as a key moderator for success in conventional PD see Chapter 2 section 2.1.2. However, when managing teams that are geographically dispersed and in various time zones, the availability of information for the global team and the clarity of task specifications becomes increasingly important to ensure tasks can be worked on autonomously to alleviate the need for overt managerial authority when coordinating such tasks. This is further highlighted in Chapter 2 section 2.2.4, where Eppinger and Chitkara [2009] discuss the importance of the clarity of tasks and activities in ensuring coordination efficiency when managing globally distributed teams. Despite this, the amount of resources required for coordinating GPD at Company A and Company B appeared to be underestimated and there was a lack of a Danish R&D representative at the global R&D facilities. The underestimation of resources required by companies for coordinating tasks during GPD has been highlighted as a key issue in previous studies [Eppinger & Chitkara, 2009].

To fully investigate the cause-effect relationship that challenges such as *Cultural differences, Communication* and *Knowledge sharing* have on success in GPD at the project-level, observations of three GPD projects at Company A and Company B were conducted and the findings from these are presented in the following section.

4.2.3.2. Approaches to managing GPD projects

During the three GPD projects at Company A and Company B (see Chapter 3 sections 3.6.3.2 and 3.6.5.2 for background of projects), various management approaches were adopted to minimise the risk of: the challenges outlined previously; and GPD project failure. These management approaches related to:

- The level of project governance - The level of control applied in the project in order to mitigate the risk of project failure.
- The modularity of the product – The separation of the product into modules to allow for the segregation of work packages within the global R&D team.
- The modularity of the PD process – The separation of the PD process into tasks and activities that could be distributed globally and worked on autonomously.

Eppinger and Chitkara [2009] describe such approaches as important for successfully managing GPD see Chapter 2 section 2.2.4.

The management approaches impacted the three GPD projects in relation to:

- The complexity of tasks - The complexity of the tasks and activities of the global R&D teams in relation to the product to be developed.
- The alignment of interests - The cohesiveness of the completed tasks and activities between global and local R&D teams.
- The workload of project management - The workload of the project manager as a result of the global collaborations.

A detailed description of the specific management approaches and the effects on the three GPD projects at Company A and Company B can be referred to in paper VI and is further discussed in the following section.

To allow for comparison within and across the three projects, the management approaches and effects on the GPD projects were rated (see Table 4-5) and a meaningful interpretation of these results is presented in the following section.

		Company A	Company B	
		Project I	Project II	Project III
Management approaches	Level of project governance.	4	4	3
	Modularity of PD process	2	4	4
	Modularity of product	n/a	4	n/a
The effect on GPD	Complexity of tasks	1	1	1
	Alignment of interests	1	3	4
	Workload of Project management	4	4	2

Note: Rated from low (1) to high (4)

Table 4-5 Data matrix: Comparison of management approaches and the effects on PD across and within the observed GPD projects

4.2.3.3. The influence on success at the project-level

In Projects I and II the Danish R&D reduced the complexity of tasks at the global R&D in order to reduce the level of project uncertainty, which restricted the global engineers innovative freedom and hence, the level of project governance from the Danish R&D was high (Figure 4-6).

At Company A, Project I was introduced to the Indian engineers as a ‘Pilot’ GPD project, where the solution was known by the Danish engineers from the outset to reduce the risk of project failure. The Danish engineers expected resource consumption to be kept low during the project with the intention of developing one or two high quality solutions to the problem in hand. Despite this and as a result of an in-depth root cause analysis conducted by the Indian engineers during the early planning stage of the project, a large number of complex solutions were proposed by the Indian engineers that would positively impact additional product variants at the company and hence, add value to the ‘Pilot’ project. The proposals were rejected by the Danish engineers as they were considered too ambitious, which created confusion among the Indian engineers in terms of the expectations and goals for the project. The extensive analysis and solution development by the Indian engineers resulted in design rework and delayed design approvals and was a key factor contributing to the project being delayed by two and a half months. Despite involving the Indian engineers from the early stages of the project, their input during the development of the product was restricted as the solution was already known by the Danish engineers to reduce the risk of project failure. As a result, the complexity of tasks and innovative freedom of the skilled Indian engineers was reduced and resulted in a misalignment of expectations and design rework.

At Company B, collocating globally dispersed engineering teams during PD projects, in particular during the early planning stages of GPD projects, was considered an important approach to ensure the alignment of interests within the globally dispersed project teams. However, in Project II, it was not possible to collocate the Chinese and Danish engineers and therefore, the Chinese engineers were introduced to the project during stage 3; where the main design of the product and key decisions regarding its development were already fixed. This routinised the development tasks for the skilled Chinese engineers and left little manoeuvrability for product design changes. At times, this resulted in design rework as when the Chinese engineers attempted to improve the main design of the product, they discovered that the Danish engineers had already attempted the same improvements unsuccessfully. Such scenarios were demotivating for the skilled Chinese engineers as despite the high complexity of the product to be developed; their freedom to develop was restricted.

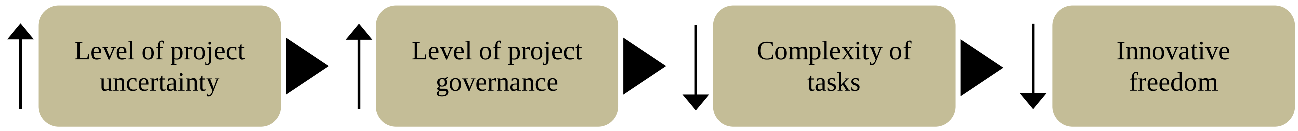

Figure 4-6 The cause-effect relationships of the level of project governance on GPD project success

The low modularity of the PD process in Project I at Company A resulted in an increased workload for the Danish R&D and a lack of cohesiveness between completed tasks with Danish and Indian engineers, which was a key cause for project time delays and design rework (Figure 4-7).

At Company A, the Danish project manager recommended following the digitalised PD process during Project I (see Figure 3-4) with the intention to: (1) reduce negotiations between the Indian and Danish engineers regarding the prioritisation and sequence of tasks; (2) allow the distributed engineers to work concurrently; and (3) to support behavioural alignment within the project team. Each stage in the PD process consisted of standardised tasks to be completed before moving to the following stage, which is a typical approach for conducting PD projects in manufacturing companies (Figure 2-1). However, and despite recommendations from the Danish project manager to follow a single process during the project, the Indian engineers planned their activities according to a six sigma process they had recently received training in due to their lack of familiarity with the guidelines in the standard PD process at the company. This influenced the prioritisation of tasks within the project team during the early stages of the project and resulted in project time delays. For example, the Danish project manager spent considerable time during the concept development stage in re-aligning the tasks completed by the Indian engineers with those completed by the Danish engineers and hence, increased the workload for the Danish project manager.

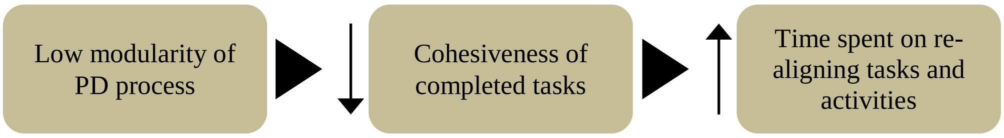

Figure 4-7 The cause-effect relationship of the level of PD process modularity on GPD project success

Similar to Project I and II, the level of governance was relatively high and the complexity of tasks was low in Project III at Company B. In contrast, the amount of time the Danish project manager spent coordinating tasks with the global team appeared to be reduced and the alignment of interests within the team increased.

At Company B, the stages in the standard PD process (Figure 3-5) were adopted during both Project II and Project III. In addition to the sequential stages in the PD process, the procedure was supplemented by techniques commonly found in agile PD; where the stages in the process were broken down into small and intense work streams named ‘Project sprints’ [Takeuchi & Nonaka, 1984], which typically lasted four weeks and with the aim of reducing PD time. Preceding the sprints, an extended project meeting was held at the Danish R&D facility including key project members with the aim of mapping tasks and activities to be completed for the next four week ‘Project sprint’. During these extended project planning meetings, the Polish engineers involved in Project III were collocated at the Danish R&D facility and were heavily involved with the planning of tasks for the next four week ‘Project sprint’. This involvement resulted in the creation of additional documentation for the collaboration to clarify: (1) the critical communication channels in the project; and (2) the understanding towards key project terminology across the global engineers, which reduced the dependency on the Danish project manager for such information and hence, reduced the workload of the project manager. However, given the increased distance between engineers in Project II, it was not possible to collocate the Danish and Chinese engineers during the project planning meetings.

The collocated meetings at early planning stages in Project III alleviated the coordination of tasks for the project manager as key project issues were discussed in an open forum, which further supported in aligning the interests in the project team and reduced negotiations regarding task prioritisation. Furthermore, the early involvement of the Polish R&D in key decisions related to the conceptualisation of the product created a high level of project ownership and motivation in the global R&D team and supported the alignment of interests.

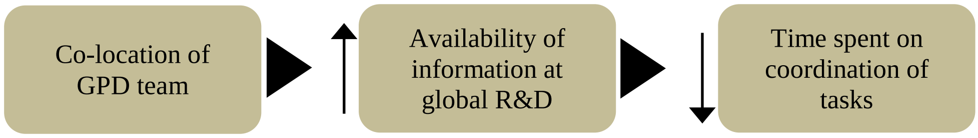

Figure 4-8 The cause-effect relationship of team proximity on the availability of information in GPD projects

Figure 4-9 The cause effect relationship of including global R&D in the early planning stages in GPD projects

The findings exemplify how different approaches to managing GPD at Company A and Company B both positively and negatively influenced success in the observed GPD projects. A number of propositions were developed based on the findings and can be referred to in paper VI.

The key challenges experienced in Company A and Company B with the global R&D resulted in a number of management approaches to mitigate the risks of project failure. This effected the GPD projects in terms of the *Complexity of tasks*, *Alignment of interests* and *Workload of the project management*, which in turn both positively and negatively influenced the success of the observed GPD projects. An overview of the key factors influencing success in the three GPD projects at Company A and Company B is illustrated in Figure 4-10.

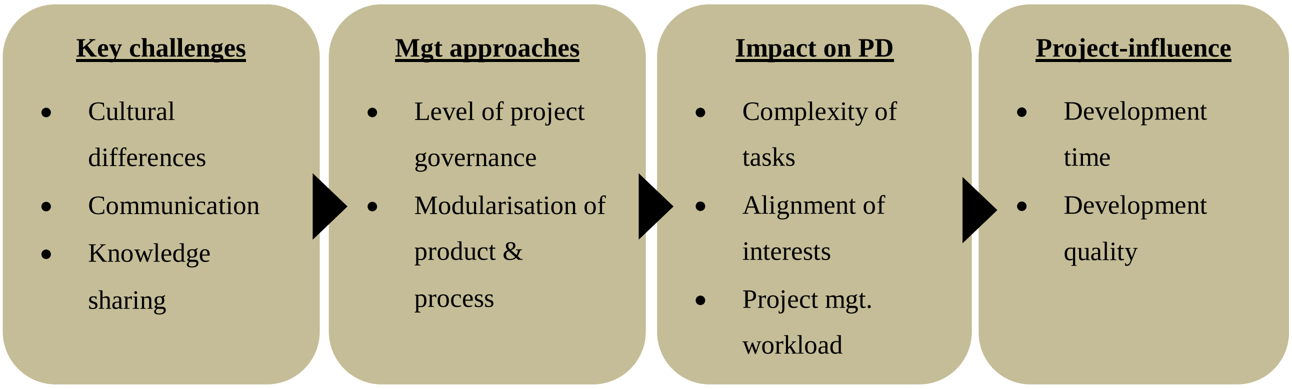

Figure 4-10 The key factors influencing success of the three GPD projects at Company A and Company B

4.2.4. Summary

The previous section presented the key findings from study two. The multiple case studies addressed research question two in Table 4-1. The specific objectives of the study were:

a) To elucidate the current practice for selecting KPIs in GPD.
b) To investigate how KPIs monitor both the negative and positive impacts in GPD at a project-level.
c) To identify the key factors influencing success in GPD at a project-level.

In relation to these objectives, the findings presented contribute to the advancement of knowledge by providing unique insight towards key cause-effect relationships of the factors influencing the success in GPD, which is seldom addressed in literature with multiple longitudinal case studies in GPD at the project-level, providing the basis for researchers and practitioners to develop practical tools in GPD. Furthermore, the study builds on previous studies in the field of GPD, which highlight the importance of selecting KPIs to support the identification and avoidance of problems as they arise [Christodoulou *et al.*, 2007, Hansen & Ahmed-Kristensen, 2012], by developing an understanding towards the selection and application of KPIs in accordance with key challenges encountered in GPD at the project-level.

4.3 Discussion of key findings

The key findings from the two studies are discussed with the relevant literature according to the key areas to which they build knowledge in the following sections. Figure 4-11 illustrates: the two studies conducted at the descriptive study I stage of this research project; the main objectives of these studies, which were formulated to address the research questions in this project (see Table 4-1); and the key areas to which the studies build knowledge.

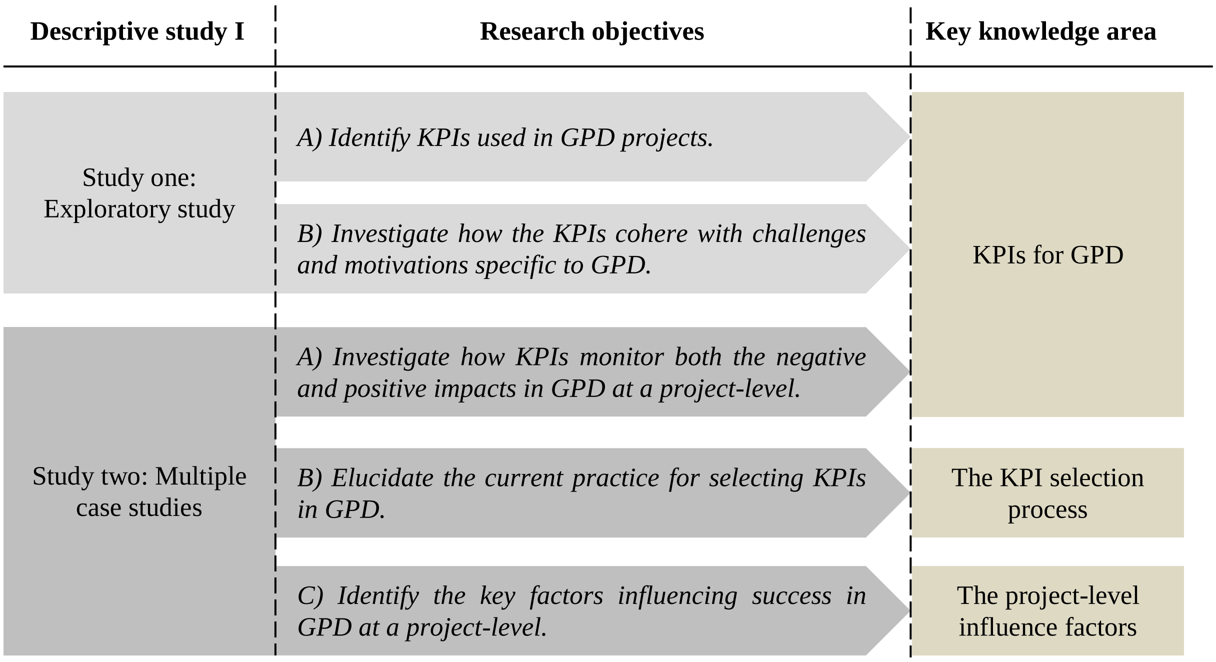

Figure 4-11 Descriptive study I stage in relation to the research objectives and the contribution to key knowledge areas.

4.3.1. KPIs for GPD projects

The KPIs identified during the descriptive study I stage of this research project are presented in Table 4-6. Similar to previous studies, which identify KPIs in conventional PD projects [Griffin & Page, 1996, Gries & Restrepo, 2011] and for business processes in general [Kaplan & Norton, 1992], a set of high-level performance dimensions were developed by the researchers in this research project and the identified KPIs were grouped according to these dimensions. Each of the performance dimensions and the corresponding KPIs are discussed in the following sections.

Performance dimension	Key performance indicator	Study one	Study two
Product development time	Break-even time	✓	
	Project lead time	✓	✓
	Project plan status	✓	
	No. of project goals met on time	✓	
	Cost of project delay		✓
Product development cost	Return on Investment	✓	✓
	Margin goals met	✓	
	Development cost	✓	✓
	Profit goals met	✓	
Customer-based	Market position	✓	
	Customer satisfaction	✓	✓
	Market share	✓	
Project specific	Capability of supplier delivery*	✓	✓
	No. of solved work packages*	✓	
	No. of agreements kept*	✓	
	No. of problems during project*	✓	✓
	Frequency of communication problems*	✓	
	Availability of documentation*	✓	✓
	Frequency of process problems*	✓	
	Internal design expert feedback		✓
	No. of product lifecycles		✓
Learning and growth	No. of sales from new location*	✓	
	Leads to future operations	✓	
	Percentage of new product sales	✓	
	No. of new projects	✓	
	No. of new alliances*	✓	
	No. of patents	✓	

Note: *Other KPIs that could not be categorised according to common KPIs in conventional PD.

Table 4-6 KPIs identified during the descriptive study I stage

4.3.1.1. Product development time

There were five KPIs identified that were primarily concerned with the measurement of PD time, with *Project lead time* identified in both Study one and Study two. PD time, and in particular the lead time to develop the product, is often described as one of the key measures for PD project performance [Krishnan & Ulrich, 2001] and is a key element of the traditional iron triangle [Toor & Ogunlana, 2010]. For business processes in general, Kaplan and Norton [1992] include such measures in the Balanced Scorecard within the *Internal* performance dimension, which aims to identify what a company must excel at. KPIs that measure PD time are applicable across a broad range of projects [Griffin & Page, 1996]. Although the KPIs within this dimension are identifiable within conventional PD projects, their application in GPD projects is equally important given the difficulties of keeping deadlines when managing projects that involve globally distributed engineering teams, which is exemplified in section 4.2.2, and further confirmed in literature [Scrivener *et al.*, 2003].

4.3.1.2. Product development cost

The KPIs identified for the measurement of PD cost in Study one and Study two primarily focussed on the fulfilment of financial targets. Similar to PD time, PD cost is a key element to the traditional iron triangle and is a critical factor when determining success across a broad variety of PD projects [Griffin & Page, 1996, Hoegl *et al.*, 2004]. When identifying measures for success and failure in PD projects, Griffin and Page [1996] group KPIs such as *Met profit goals* and *Met margin goals* within KPIs for financial success. In conventional PD, Driva [1997] and O'Donnell and Duffy [2002] highlight the tendency for practitioners to select KPIs that focus on the more tangible outcomes of PD that tend to relate to financial targets such as *Return on investment*, *Development cost*, etc. which were identified as KPIs for GPD in both Study one and Study two in this research project. However, the inclusion of both financial and non-financial KPIs when measuring performance is important [Neely *et al.*, 2000, Ford & Sterman, 2003], particularly in environments of high uncertainty such as GPD [Hansen & Ahmed-Kristensen, 2012] and is discussed in more detail in section 4.3.1.6.

4.3.1.3. Customer-based

The customer is a key stakeholder in the development of products and hence, is integral to the success at both the project-level and for the business as a whole. There are several bodies of work that identify customer-based KPIs in conventional PD studies [Griffin & Page, 1996] and also studies that investigate the use of customer-based KPIs for business processes in general [Kaplan & Norton, 1992, Neely, 2002]. In Study one, *Market position* and *Market share* are considered as business-level KPIs and focus on measuring the success in terms of business growth. Such KPIs may typically be used by top-level management when discussing strategic foresight for the company. The identification of the business-level KPIs can be explained given the high participation of top-level management during Study one. *Customer satisfaction* was identified as a

KPI for GPD in both Study one and Study two, which further outlines the importance of this KPI for GPD at the project-level. Similar to the previous dimensions, many of the KPIs identified were also found to be common in conventional PD projects [Griffin & Page, 1996], which implies that many of the KPIs used in conventional PD projects are also important for measuring performance in GPD projects.

4.3.1.4. Project specific

In comparison to the KPIs identified for the previous dimensions, the KPIs grouped according to the project specific dimension are less tangible and may vary depending on the project management, the project itself, and the individuals that make up the project team. As discussed in Chapter 2 section 2.1.1, success at the project-level is multi-faceted and difficult to define [Toor & Ogunlana, 2010], which explains the high variability of the KPIs grouped within this dimension. Furthermore, many of the KPIs identified for GPD projects within this dimension could not be categorised according to common KPIs found in conventional PD projects such as *Capability of supplier delivery, No. of problems during project* and *Availability of documentation*, which were identified in both Study one and Study two. This implies that changing the environment where PD takes place may bring rise to additional challenges and opportunities and hence, the KPIs selected for measuring performance should adapt to the new environment. For example, in Study two the availability of documentation for the globally dispersed engineers was hindered given the proximity to the Danish headquarters and the internal processes at the company. As such, *Availability of documentation* was selected as a KPI to monitor this (see section 4.2.2.3). Changing the environment where PD takes place brings rise to additional challenges [Eppinger & Chitkara, 2009, Hansen & Ahmed-Kristensen, 2011] and as a result, the KPIs at the project specific dimension must adapt to such changes.

4.3.1.5. Learning and growth

Kaplan and Norton [1992] identified learning and growth as an important performance dimension during the development of the Balanced Scorecard, which relates to a company’s ability to launch new products, create more value for customers and improve operating efficiencies continually. Such dimension was also found to be important during the grouping of the KPIs identified for GPD in this research project. However, KPIs grouped within the learning and growth dimension were only identified during Study one. Similar to the customer-based dimension, the majority of the identified KPIs relate to business-level performance as a *result* of GPD such as *Leads to future operations*, *No. of new alliances, No of patents,* etc. rather than KPIs to be used by project management during GPD at the project-level. This can be explained given the high participation of top-level management during Study one. Furthermore, *No. of sales from new location* and *No. of new alliances* could not be categorised according to KPIs common in conventional PD, which highlights the additional opportunities for success in GPD.

The grouping of KPIs within performance dimensions is a common approach in literature to support management with the selection and application of KPIs [Griffin Page, 1996, Kaplan & Norton, 1992]. However, it is clear that the KPIs identified in Table 4-6 are applicable for measuring performance at different levels of the business. For example:

- KPIs within the performance dimensions: product development time; product development cost; and project specific performance, may be useful for project managers when measuring performance of GPD at the project-level.
- KPIs within the performance dimensions: customer-based and learning and growth, may be useful for top-level managers when evaluating the impact of GPD at the business-level.

Many of the KPIs identified for GPD projects in Table 4-6 are also common for measuring performance in conventional PD projects. However, a general criticism towards KPIs used in conventional PD projects is they are lagging in nature and hence, provide a time-delayed retrospective look on performance [Driva, 1997, Tatikonda, 2007] (see Chapter 2 section 2.3.3). The more tangible KPIs that focus on measuring the outcome of a project, such as *Project-lead time*, *Return on investment*, *Development cost*, etc. are undoubtedly important indicators of GPD project success and can provide indication towards how to improve for *future* GPD projects. However, they fail to provide the predictive insight required to avoid deviations along the process of *current* GPD projects. The following section further exemplifies this.

4.3.1.6. The application of leading and lagging KPIs in GPD projects

In study one, the majority of KPIs stated in the two surveys for measuring the motivations in GPD were lagging in nature and focussed on measuring more tangible outcomes of GPD (see section 4.1.1.1). Selecting KPIs to measure tangible outcomes was also found to be a tendency by practitioners in conventional PD [Driva, 1997, Tatikonda, 2007, Rhodes *et al.,* 2009]. However, according to O’Donnell and Duffy [2002], such indicators do not consider the trade-off between the cost of the PD process and the quality of the final product. Including KPIs to measure the less tangible factors to ensure a balanced approach to performance measurement is particularly important in cases of high uncertainty, such as PD, where the relationship between input, process and output has been described to be less direct than in more generic business processes [Tatikonda, 2007, Taisch *et al.*, 2011]. Although common KPIs in conventional PD, such as *Development cost*, *Project lead-time* and *Customer satisfaction* are also important for measuring performance in GPD projects, the application of such KPIs alone may be inadequate to provide timely information towards challenges in GPD that influence success along the process, such as cultural differences or communication difficulties. The importance of developing KPIs that measure the 'soft' factors in GPD is further highlighted in literature [Hansen & Ahmed-Kristensen, 2012].

Despite the perceived importance of the challenges: *Communication* and *Cultural differences*, the participants in Survey II found it difficult to state KPIs that monitored these in comparison to KPIs for measuring the motivations (see section 4.1.1.2). This can be expected given the difficulty with selecting KPIs to monitor less tangible factors. However, in contrast to KPIs stated for the motivations, many of the KPIs for monitoring the challenges were leading in nature and focussed on measuring factors that influenced success along the process such as *Availability of documentation*, *Frequency of process problems*, etc. This implies that adopting a challenge-oriented approach to selecting KPIs, rather than solely a goal-oriented approach, may encourage the selection of leading KPIs. Leading KPIs have been described to measure the factors impacting a process and are drivers of performance [Kaplan & Norton, 1996] and hence, can inform managers of where to make adjustments along the process and avoid the impacts [Tatikonda, 2007, Rhodes *et al.*, 2009] and is further exemplified in section 4.2.2.3 during study two. Such KPIs may be useful in the context of GPD as team proximity and cultural differences are accentuated and have a greater impact on success in comparison to conventional PD see Chapter 2 section 2.2.2.

In study two, the KPIs selected at Company A and B did not provide the sufficient feedback required to avoid the key challenges encountered along the process that influenced the success of the observed GPD projects (see section 4.2.2.2). *A lack of common vision* negatively influenced the success of the GPD projects and was a key cause for design rework and project time delays. Despite identifying *A lack of common vision* as a key challenge during a project risk assessment, leading KPIs, described as KPIs that monitor factors influencing a process and are drivers of performance [Kaplan & Norton, 1996], were not selected to monitor this. Rather, KPIs that are commonly applied in conventional PD projects, which have been described to be lagging in nature [Driva, 1997, Tatikonda, 2007, Rhodes *et al.*, 2009], such as *Development time*, *Project lead time*, *Customer satisfaction*, etc. were used and resulted in a time delayed look on performance, which was inadequate to proactively implement strategies to avoid design rework and project time delays. This resulted in solutions to the challenge being implemented on an 'as-needed' basis, which can be costly further down the process, and is further exemplified in previous studies where companies adopt a learning-by-doing approach to GPD [Hansen & Ahmed-Kristensen, 2011, Kalyandurg & Akhilesh, 2012]. This reaffirms the importance of developing KPIs that measure the 'soft' factors in GPD [Hansen & Ahmed-Kristensen, 2012] to provide the necessary indication towards deviations and hence, support with implementing precautionary strategies along the process.

The following key implications are highlighted as a result of investigating KPIs for GPD projects:

- The identification of KPIs for GPD, and the grouping of these KPIs within performance dimensions typically found in conventional PD projects [Griffin & Page, 1996] and business processes in general [Kaplan & Norton, 1992, Neely *et al*., 2002], supports with the development and selection of KPIs in GPD projects. KPIs identified and grouped within the performance dimensions: product development time; product development cost; and project specific are useful for project managers when measuring performance in GPD projects. KPIs identified and grouped within the performance dimensions: customer-based; and learning and growth are useful for top-management when evaluating the impact of GPD at the business-level.
- There is a need for the selection of leading KPIs in GPD, which monitor the challenges that influence success along the process rather than solely goal-oriented approaches common in conventional PD, which typically support the selection of lagging KPIs that measure the more tangible outcomes of a process alone.

4.3.2. The KPI selection process

The approach for selecting KPIs at Company A and Company B during the observed GPD projects was predominantly goal-oriented, without consideration towards key challenges that could influence the success of the projects, and was primarily reliant upon the deliverables mapped out in the standard PD processes at the two companies. This resulted in KPIs that focussed on measuring more tangible outcomes of the GPD projects, such as *return on investment*, *development cost, project-lead time, etc.* which are also common in conventional PD projects and have been described as lagging in nature [Driva, 1997, Tatikonda, 2007] and hence, do not provide indication in relation to the factors influencing success specific to GPD along the process.

The level of participation of the globally dispersed engineers during the selection process appeared to influence the KPIs that were selected. For example, the internal processes for the release of documents was considered an issue that could impact the availability of documentation for the Polish engineers in Project III at Company B and hence, lead to project time delays. As a result a leading KPI was selected to monitor this to allow the avoidance of project time delays (see section 4.2.2.3). When selecting purposeful KPIs, the importance of involving all stakeholders has been highlighted [Neely et al., 2000] see Chapter 2 section 2.3.4. However, it was only Project III at Company B where the global engineers were actively involved during the KPI selection process.

There was a lack of structure for selecting KPIs at Company A and Company B. The limitations of brainstorming as an approach for developing KPIs, which was adopted as an approach by the project manager at Company B, have been discussed in literature [Barr, 2014] as such approaches can lead to long lists of KPIs without a clear understanding towards the purpose.

The following key implications are highlighted as a result of investigating the KPI selection process:

- There is a need for a structured approach for the selection of KPIs at the project-level in GPD, which includes a challenge-oriented approach to selection rather than solely a goal-oriented approach typically found in conventional PD. Such approach may support the selection of leading KPIs that monitor factors influencing success along the process and hence, support project managers in setting up precautionary strategies.

4.3.3. The project-level influence factors

In Study one, the results from the two surveys, which were conducted with a broad range of Danish companies, did not result in additional motivations or challenges being stated than those identified in literature, Chapter 2 section 2.2.2, which implies that research in this area is beginning to mature. *Cultural differences*, *Communication* and *Knowledge sharing* were key challenges identified for GPD across both Study one and Study two, which is comparable to previous case studies that investigate GPD [Kalyandurg & Akhilesh, 2012, Hansen & Ahmed-Kristensen, 2011]. However, these challenges are considered to be high-level and an understanding of their impact at the project-level was required to support project management in developing precautionary strategies.

The following sections discuss the key findings in relation to the management approaches adopted to mitigate the risk of failure in the observed GPD projects during Study two; and the impact of these management approaches on project success.

4.3.3.1. The level of project governance and the influence on success

In Projects I and II where the level of governance was high, project uncertainty levels were lowered by reducing task complexity, which restricted the innovative freedom at the global R&D facilities. This can be explained given the difficulty in managing more complex tasks in GPD projects, where physical proximity is lacking and reducing task complexity has been described as an approach to avoid cultural misunderstandings and design rework [Littler *et al.,* 1995, Hansen & Ahmed-Kristensen, 2011]. Furthermore, maintaining a high level of control at the parent company has been described as a strategy to counteract the accentuated challenges experienced with GPD projects, in particular for protecting the company's core competencies and dealing with a lack of trust towards competency levels in GPD teams [Eppinger & Chitkara, 2009, Hansen & Ahmed-Kristensen, 2011]. However, in Projects I and II, the reduction in task complexity and the lack of freedom to develop for the global engineers resulted in a misalignment of interests in the project team and design rework as a number of more ambitious solution propositions were rejected. In comparison to conventional PD where cultural diversity is reduced and uncertain and ambiguous environments have been encouraged given the positive association with project success [Hoegl *et al.,* 2004, Edmondson and Nembhard, 2009], Project I and II indicate how the level of uncertainty is reduced in GPD projects to avoid cultural misunderstandings and design rework. However, providing skilled engineers, which are globally distributed, with sufficient responsibility towards development tasks while maintaining task stability is important and is further confirmed in literature [Eppinger & Chitkara, 2009, Kalyandurg & Akhilesh, 2012].

4.3.3.2. The modularity of the PD process and the influence on success

The lack of clearly defined tasks in the PD process in Project I resulted in a lack of cohesiveness between tasks completed in the GPD team and hence, increased the workload towards coordination activities for the project manager. In Projects II and III, the tasks and activities were planned by the GPD team according to four week 'Project sprints', which encouraged the adherence to the PD process and played an important role in reducing the coordination activities for the project manager. A clear understanding towards the systematic approach for the development of products was found to be important in local, cross functional PD [Hales, 1987)] and is further compounded in GPD given the need for the alignment of work packages in multiple geographic locations. In comparison to conventional PD, informal communications and interactions that have been found to support the alignment of interests within the team [McDermott, 1999] are restricted in GPD projects and the requirement for clearly defined, decomposed PD tasks and activities within the PD process is increased [Eppinger & Chitkara, 2009, Hansen & Ahmed-Kristensen, 2012].

4.3.3.3. The inclusion of globally dispersed engineers during the early planning stages of GPD projects

Similar to Project I and II, the level of governance was relatively high and the complexity of tasks was low in Project III. In contrast, the amount of time the Danish project manager spent coordinating tasks and activities appeared to be reduced and the alignment of interests within the team increased. The opportunity to collocate the Polish engineers and their high involvement during strategic planning sessions in Project III created a high level of project commitment and supported the alignment of interests within the project team. The early involvement of the Polish engineers in key decisions related to the development of the product in project III further supported this. These findings are confirmed in literature where the inclusion of geographically dispersed global partners during the early planning stages in GPD projects, has been described as an approach for avoiding the misalignment of interests during the later stages of GPD projects [Littler *et al.*, 1995, McDonough *et al.*, 1999, Kleinsmann & Valkenburg, 2008].

The following key implications are highlighted as a result of investigating the factors influencing the success at the project-level in GPD:

- The importance of: (1) providing global partners with sufficient responsibility towards development tasks while maintaining task stability; (2) ensuring modular interfaces are clearly defined with localised project management at the global R&D to monitor this; and (3) collocating teams during critical stages of GPD projects, such as the early planning stages where key project decisions are made, to increase the level of project commitment and ownership.

- Proactively understanding key cause-effect relationships between: (1) the key motivations that represent the desirable outcome for the GPD project e.g. *Reduce time to market*; and (2) the key challenges that influence success towards this outcome e.g. *A lack of common vision* is an important step to support the development of necessary precautionary strategies when managing GPD projects.

4.4 Key implications for academic and industrial communities

The current research study builds on previous studies in the field of GPD [Christodoulou *et al.*, 2007, Hansen & Ahmed-Kristensen, 2012] that highlight the importance for developing KPIs to support management in making informed decisions during GPD projects. The study is unique as it adopts a multiple longitudinal case study approach, which is one of very few studies conducted in an industry setting that focus on real engineering design activities in a global context.

As a result of the studies conducted during the descriptive study I stage, the following key research implications are highlighted:

- The identification and understanding towards KPIs specific for the management and operation of GPD projects builds on studies that investigate KPIs in conventional PD projects [Griffin & Page, 1996, O'Donnell & Duffy, 2002].
- The lack of understanding towards the concept of *leading* KPIs in engineering design practice, despite the establishment of the concept in literature for business processes in general [Kaplan & Norton, 1992], was highlighted and indicates the need to support the development of such KPIs in future studies.
- The in-depth nature of the multiple case studies enabled observed influence factors to be traced back to their initial causes and hence, informs both researchers and practitioners regarding the necessary precautionary strategies to be developed to better manage the impacts and support in managing the transition from conventional PD to GPD.
- The coding scheme developed for the analysis of data collected is a useful framework that provides guidance towards key factors important for future research studies investigating the selection and application of KPIs in GPD projects.

As a result of the studies conducted during the descriptive study I stage, the following key managerial implications are highlighted:

- Proactively understanding key cause-effect relationships between: (1) the key motivations that represent the desirable outcome for the GPD project e.g. *Reduce time to market*; and (2) the key challenges that influence success towards this outcome e.g. *A lack of common vision* is an important step to support the development of necessary precautionary strategies when managing GPD projects.

- To better manage the impacts on GPD projects, practitioners should: (1) provide global partners with sufficient responsibility towards development tasks while maintaining task stability; (2) ensure modular interfaces are clearly defined, with localised project management at the global R&D to monitor this; and (3) collocate teams during critical stages of GPD projects, such as the early planning phase where key project decisions are made, to ensure project commitment.
- A challenge oriented-approach should be adopted to support the selection and documentation of: (1) *lagging* KPIs to measure the performance of past activity once the project is complete in relation to the desirable outcomes and motivations for GPD; and (2) *leading* KPIs to monitor the key challenges that influence the success towards the desired outcome and hence, provide timely feedback to support the proactive implementation of strategies to avoid impacts on success along the process.

Overall, the study builds knowledge regarding the global dispersion of engineering design activities in practice, which is seldom addressed with multiple longitudinal observational studies at the project-level in GPD, providing the basis for researchers and practitioners to develop practical tools in GPD.

4.5 Conclusions

The results from the two studies conducted at the descriptive study I stage contributed to the advancement of knowledge towards the current practice of performance measurement in GPD, in relation to the selection and application of KPIs, and developed an understanding towards key factors that influence the success at the project-level, which is seldom addressed in literature in the context of GPD.

- Study one: Exploratory study contributes to the advancement of knowledge towards the selection of KPIs to measure performance in the context of PD when engineering teams are globally dispersed, which builds on studies that investigate this in conventional PD that typically consists of local, cross-functional members [Griffin & Page, 1996, O’Donnell & Duffy, 2002]. Furthermore, Survey II in the exploratory study identifies KPIs selected as a result of key challenges in comparison to common approaches in literature that identify KPIs that are goal-oriented.

From the results in Survey I, which included 28 Danish companies, and Survey II, which included 16 Danish companies, *Cost reductions*, *Access to new resources; Flexibility & Scalability* and *Reduce time to market* were stated as key motivations for pursuing GPD. The most frequently stated KPIs for measuring the motivations across Survey I and II were: *Development cost*; *Project lead-time;* and *Customer satisfaction*. The majority of KPIs stated for measuring the motivations in GPD were found to be lagging in nature and focussed on measuring more tangible and financial outcomes of GPD. However, the application of lagging KPIs alone traditionally used in conventional PD provides a time delayed look on performance, rather than the predictive insight required to support the avoidance of key challenges that influence success along the process, and hence lagging KPIs alone may be insufficient considering the additional challenges in the context of GPD.

In Survey II, *Communication*, *Cultural differences* and *Knowledge sharing* were stated as key challenges in GPD. In comparison to the motivations, participants experienced difficulties in stating KPIs for monitoring the less tangible key challenges in GPD, despite the perceived importance of the challenges. However, 6 of the 8 KPIs that were stated could not be categorised according to KPIs commonly used in conventional PD and related to communication, documentation and general process/ project issues, which implies that additional KPIs for monitoring the challenges in GPD are required. Furthermore, many of the KPIs stated for monitoring the key challenges, focussed on measuring factors that influenced the success along the process such as, *Availability of documentation*, *Frequency of communication problems*, *Frequency of process problems, etc.* and were leading in nature. This implies that adopting a challenge-oriented approach to selecting KPIs, rather than solely a goal-oriented approach, may encourage the selection of leading KPIs that inform management of where to make adjustments along the process to avoid the influence on success. The key findings from the exploratory study highlight the need for the selection of leading KPIs in GPD, which monitor the challenges that influence success along the process rather than solely goal-oriented approaches common in conventional PD, which typically support the selection of lagging KPIs that measure the outcome of a process alone.

- <u>Study two: Multiple case studies</u> contribute to the advancement of knowledge by providing unique insight towards key cause-effect relationships of the factors influencing success in GPD, which is seldom addressed in literature with multiple longitudinal case studies in GPD at the project-level, providing the basis for researchers and practitioners to develop practical tools in GPD. Furthermore, the study builds on previous studies in the field of GPD, which highlight the importance of selecting KPIs to support the identification and avoidance of problems as they arise [Christodoulou *et al.*, 2007, Hansen & Ahmed-Kristensen, 2012], by developing an understanding towards the selection and application of KPIs in accordance with key challenges encountered in GPD at the project-level.

From the results of the interviews at Company A and Company B, *Communication*, *Cultural differences* and *Knowledge sharing* were stated as key challenges in GPD, which increased the requirement for clearly defined tasks at the global R&D facilities as the frequency of communication and availability of information was reduced given the global dispersion of the teams. The challenges were comparable to those stated during the exploratory study, which reaffirms the importance of the challenges in GPD. As a result of these challenges, adjustments were made during the observed GPD projects in relation to the level of project governance and modularity of the PD process in the attempt to reduce the risk of project failure and alleviate the dependency on the Danish R&D. However, the adjustments impacted the *Complexity of tasks*, *Alignment of interests* and *Workload of the project management* and adversely impacted the success of the GPD projects as the lack of balance between the level of responsibility and control negatively influenced the motivation of the engineers at the global R&D facilities. Furthermore, the lack of understanding in relation to the tasks in the standard PD process resulted in the misalignment of work completed. Key findings from the multiple case studies highlight the importance of proactively understanding key cause-effect relationships between: (1) the key motivations that represent the desirable outcome for the GPD project e.g. *Reduce time to market*; and (2) the key challenges that influence success towards this outcome e.g. *A lack of common vision* as an important step to support the development of necessary precautionary strategies when managing GPD projects.

The approach for the selection of KPIs at Company A and Company B was predominantly goal-oriented without the consideration towards the key challenges in GPD and the majority of KPIs could be grouped according to performance dimensions common in conventional PD. However, 4 other KPIs were selected during the GPD projects that could not be categorised according to these dimensions and were a result of key challenges encountered during the GPD projects in relation to

A lack of common vision and *Documentation*. This reaffirms the need highlighted during the exploratory study for additional KPIs than those commonly found in conventional PD, in particular for monitoring the key challenges in GPD.

The majority of the selected KPIs during the observed GPD projects were lagging in nature and hence, did not provide the timely feedback required to avoid the key challenges encountered along the process that influenced the success of the projects. Despite identifying *A lack of common vision* as a key challenge during a project risk assessment, leading KPIs, which monitor factors influencing a process and are drivers of performance, were not selected to monitor this. Rather, the lagging KPIs used resulted in a time delayed look on performance, which was inadequate to proactively implement strategies to avoid design rework and project time delays. This reaffirms the need expressed in literature for developing KPIs to support the identification and avoidance of problems as they arise. Key findings from the multiple case studies highlight the need for a structured approach for the selection of KPIs at the project-level in GPD, which includes a challenge-oriented approach rather than solely a goal-oriented approach typically found in conventional PD. Such approach may support the selection of leading KPIs that monitor factors influencing success along the process and hence, support project managers in setting up precautionary strategies.

The broad variety of KPIs for measuring performance identified in both conventional and GPD projects, see Chapter 2 section 2.3.3 and Chapter 4 section 4.3.1, further highlights the difficulties in proposing a set of generalisable KPIs that can be suitably applied at the project-level in GPD. As exemplified in Chapter 4 section 4.2.2, changing the environment where PD takes place brings rise to additional challenges and the KPIs selected must adapt to such challenges. Based on this understanding, providing a structured approach to support the process of *selecting* KPIs in the context of GPD is considered an important area for the development of a method to support performance measurement in GPD projects.

Based on the results from the exploratory study and multiple cases studies, a need was identified to support the identification of key factors influencing success in GPD and provide a structured approach for the selection and documentation of KPIs to monitor and measure these. Such approach could provide the necessary feedback to enable adjustments along the process and avoid the impacts on success. The method of support and preliminary evaluation is presented in Chapter 5.

Chapter 5 Development and evaluation of the KPI selection toolkit

5.1 Introduction

This chapter describes the development of the support method (the prescriptive study) and the results from the evaluation of the proposed support method (the descriptive study II) as part of the overall research methodology employed during this research project. The development and evaluation of the support method can also be referred to in paper VII (Appendix 5).

This chapter is structured accordingly:

- The development of the support method for the identification and monitoring of key factors influencing success in GPD at the project-level is presented in sections 5.2 and 5.3 (the prescriptive study).
- The results from the preliminary evaluation of the support method, which was conducted at a third company case during study three of this research project, are presented in section 5.4 (the descriptive study II).

5.2 Development of the support method

The aim of the prescriptive study was to develop a method to support the selection of KPIs that provides management with timely feedback on performance in GPD projects, addressing research question 3 in Chapter 3 section 3.2. The specific objectives of the study were:

a) Develop a method that supports the identification and prioritisation of critical factors influencing success in GPD projects.
b) Develop a method that supports the selection and documentation of leading and lagging KPIs in GPD projects.

The development of the support method was based on the following key findings from Chapter 4:

- The lack of understanding towards leading and lagging KPIs in industry.

- There was a lack of a structured approach for the selection of KPIs in GPD at the project-level to provide the necessary guidance to identify key factors influencing success and develop and document KPIs for monitoring and measuring these.
- KPIs used in GPD projects are predominantly lagging in nature and do not provide the necessary feedback to avoid key challenges, such as a lack of common vision that influence the success along the process.

Based on these findings a number of issues were raised and various approaches towards the development of the support method to address these issues were considered.

The following issues were considered important to inform the development of the support method and its application in industry:

- There is a requirement to develop an understanding towards the relationship between leading and lagging KPIs to ensure the purpose of the KPIs is understood.
- There is a requirement to support the early identification and prioritisation of key cause-effect relationships at the project-level in GPD in relation to: (1) the key motivations that represent the desirable outcome of GPD projects e.g. Reductions in time to market; and (2) the key challenges that influence success towards this outcome e.g. A lack of common vision in the project team. This understanding provides the basis for precautionary strategies to be set.
- There is a requirement for a structured approach to support the selection and documentation of: (1) Lagging KPIs to measure performance of past activity once a GPD project is complete; and (2) Leading KPIs to monitor key factors influencing success towards the desired outcome and hence, provide timely feedback to support the proactive implementation of strategies to avoid the influence factors along the process.

During the prescriptive study, these issues, together with the support method developed (see Chapter 5 section 5.3) were presented to the participating companies in the descriptive study I stage of this research project (Company A and Company B) and during a workshop that focussed on GPD that involved over 60 Danish companies who currently globalised parts of their PD activities. There were two key implications as a result of this:

1. Valuable feedback from practitioners was received that further supported the development of the support method, which is discussed in more detail in the following sections.
2. The key issues raised, together with the ongoing development of the support method, were partly verified with industry.

In addition to the key findings from the descriptive study I stage, key elements from the literature review further supported the development of the support method with indications to these discussed in more detail in the following sections.

In accordance with the issues raised earlier in section 5.2, the main contributions of the support method to this research project were:

- The method of support introduces a shift from traditional goal-oriented approaches to the selection of KPIs to include a challenge-oriented approach, which supports the selection of both lagging and also leading KPIs at the project-level in GPD that provide the necessary feedback to develop precautionary strategies to minimise the risk of factors influencing success along the process.
- The identification and prioritisation of key factors influencing the success, prior to the selection of KPIs, supports in creating a common vision within the project team.
- The method of support encourages the documentation of the process and hence, increases the availability of information, enabling key knowledge and experience to be transferred to future projects.

5.3 The KPI selection toolkit

The support method developed, namely: the KPI selection toolkit is presented in this section and can be referred to in paper VII. The KPI selection toolkit consists of three phases which aim to support project managers in manufacturing companies to execute a KPI selection workshop in PD projects consisting of globally distributed design teams. The three phases include: (1) Clarify key concepts, which aims to develop an understanding towards key performance measurement concepts; (2) KPI selection, which provides a structured approach for the selection of project-level KPIs in GPD; and (3) Monitor and measure, which supports the documentation and reporting of selected KPIs (Figure 5-1). The three phases require facilitation and are conducted during a workshop at the company, which is expected to last approximately four hours. Each of the phases are described in more detail in the following section and supporting documentation for the KPI selection toolkit can be referred to in Appendix 4.

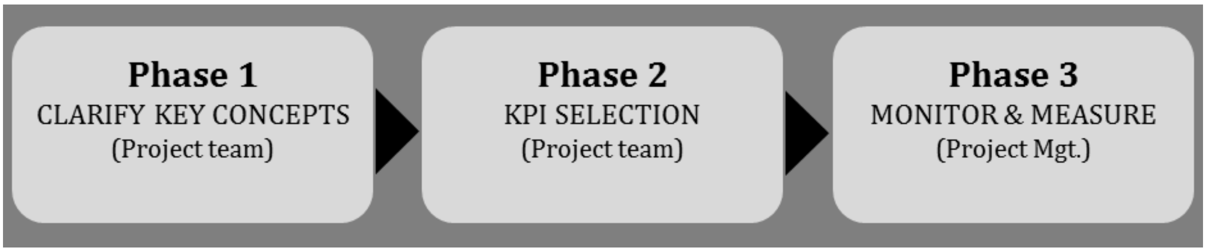

Figure 5-1 The three phase approach in the KPI selection toolkit

5.3.1 Guidelines for the three phase approach in the KPI selection toolkit

5.3.1.1 Phase 1 – Clarify key concepts

The aim of Phase 1 is to develop an understanding towards key concepts for performance measurement in the GPD project team in relation to: performance measurement to support decision making; the selection and application of KPIs; and the relationship between leading and lagging KPIs. In particular, the relationship between leading and lagging KPIs is clarified with key examples based on results from the descriptive study I stage of this research project see Chapter 4 section 4.2.2.2 and 4.2.2.3. Phase 1 requires participation from key members of the GPD project team to ensure the purpose of the selection and application of KPIs is understood and to gain commitment towards this from the project team prior to moving to Phase 2. The importance of this was highlighted during the descriptive study I stage see Chapter 4 section 4.2.1 and also based on feedback during the presentation of the KPI selection toolkit from Company A and Company B. The estimated time for completing Phase 1 is 30 minutes.

5.3.1.2 Phase 2 – KPI selection

Phase 2 requires the participation of key members of the GPD project team and is based on the framework illustrated in Figure 5-2. The framework, which was developed based on key findings from the descriptive study I stage and key elements from the literature review aims to provide a structured approach for the identification and prioritisation of key factors influencing success and the selection and documentation of KPIs to monitor and measure these in GPD projects. Three levels of performance measurement are indicated in the framework, namely: the business-level; the project-level; and the task-level. In this research project the focus is at the project-level. However, cohesion between KPIs selected at the three levels is important.

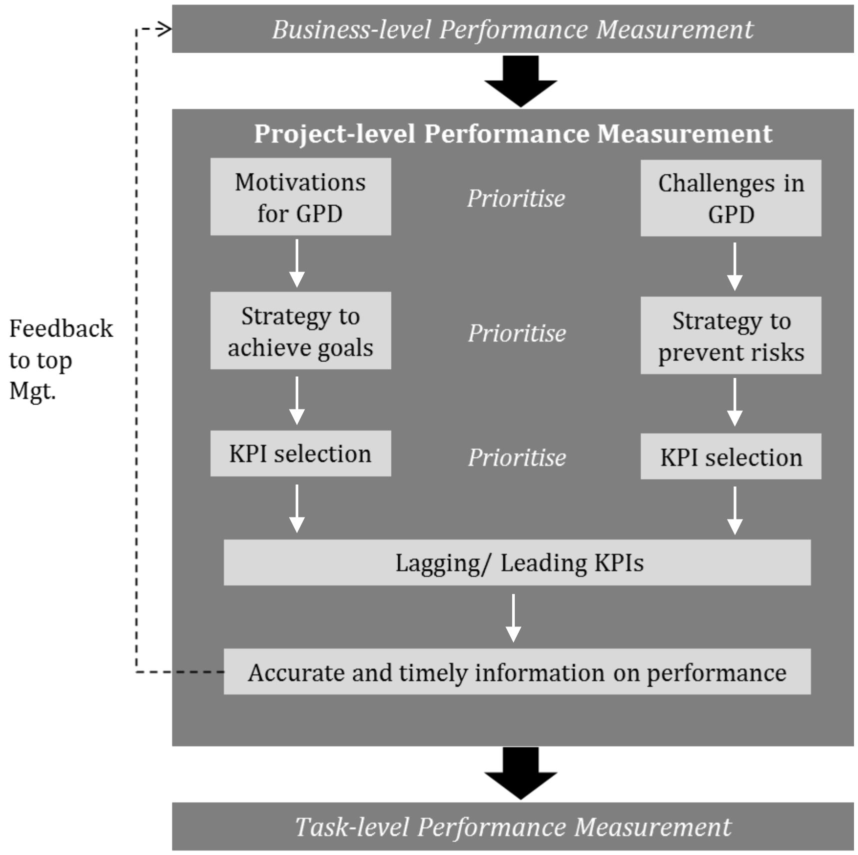

Figure 5-2 Framework to support the selection of project-level KPIs in GPD during Phase 2 of the KPI selection toolkit

Based on the framework, the following steps are required for the completion of phase 2:

1. Key motivations and challenges specific for the GPD project at the company are identified and prioritised. To support this identification, the key motivations and challenges for GPD, as highlighted in literature (Chapter 2 section 2.2.2) and further confirmed during the descriptive study I stage (Chapter 4 section 4.1.1 and 4.2.3), are presented to the project team. For example *a lack of common vision, cultural differences, poor documentation etc.* as key challenges and *cost reductions, reduce time to market, etc*. as key motivations. The cause-effect relationships between: (1) the key motivations that represent the desired outcome for the project; and (2) the key challenges that influence the success at the project-level towards this outcome are identified and mapped to a Fishbone diagram, which has been adopted by previous authors attempting to understand the key effects of outsourcing in general [Kitcher *et al.*, 2013]. Strategies to prevent the identified influence on success and achieve the desired outcome are planned, which has previously been recommended for the development of KPIs [Neely *et al.*, 2000]. The development of strategies is further

supported based on key findings in the descriptive study I stage (Chapter 4 section 4.4), for example the modularisation of the PD process or the collocation of the global R&D during early stages of the GPD project.

2. Leading KPIs are developed based on the planned strategies to avoid the identified influence on success as a result of the key challenges identified and support the identification of deviations along the process. Lagging KPIs are developed to measure the achievement towards the desired outcome of the GPD project. KPIs for GPD identified during the descriptive study I stage are provided to support this process (see Table 4-6), for example *Availability of documentation, Frequency of process problems, Development cost, etc*.

3. The planned strategies and KPIs developed are mapped to the PD process followed at the company for the completion of the GPD project, indicating where along the process the strategies require implementing and the frequency the KPIs require monitoring and measuring along the process.

Phase 2 of the KPI selection toolkit is reviewed at important intervals, such as after key project milestones in the GPD project, to ensure the KPIs change as circumstances change. The estimated time for completing Phase 2 is 120 minutes.

5.3.1.3 Phase 3 – Monitor and measure

The aim of Phase 3 is to support the documentation and reporting of the KPIs developed. Phase 3 requires the participation of the project manager from the GPD project team or the main responsible for monitoring and measuring performance. The developed KPIs are documented in a KPI template to ensure the purpose and formula for measuring the KPIs is clearly defined. The KPI template is based on similar templates proposed in literature see Chapter 2 section 2.3.1 and includes information related to: the Purpose of the KPI, the key influence factor(s) it relates to, the main responsible for the KPI and the frequency of measurement and targets. In additon to the performance measure record sheet [Neely *et al.,* 1997], the KPI template encourages the project manager to document the relationship between the leading or lagging KPI that the developed KPI relates to in order to ensure the relationship between the two is understood. Finally, the KPI is entered into a KPI one pager, which enables clear visualisation and monitoring of the KPI in accordance with the project timing and targets outlined in the KPI template and provides indication towards the key achievements, the key challenges and the next steps for measurement. The KPI one pager is kept up to date by the project manager in accordance with the frequency of measurement indicated in the KPI template. The estimated time for completing phase 3 is 30 minutes.

Based on feedback during the presentation of the KPI selection toolkit from Company A and Company B, the importance of understanding: (1) the maturity of the GPD project; and (2) the experience with selecting KPIs at the company, was highlighted. As a result, a process to assess this maturity was developed and is to be conducted prior to implementing the KPI selection toolkit (Figure 5-3). This enables the following:

- The experience with selecting and using KPIs in the project team and the maturity of the GPD project are assessed to determine the starting phase in the KPI selection toolkit. For example, if key concepts for performance measurement are understood then the starting point in the toolkit is Phase 2.
- The KPI selection toolkit can be tailored to the need of practitioners and allows the toolkit to be integrated into current procedures at the company. For example, if a risk assessment has been conducted prior to implementing the toolkit in a GPD project, this may be coupled with the approach for identifying critical influence factors during Phase 2 and hence, the starting point would be the selection of KPIs in Phase 2.

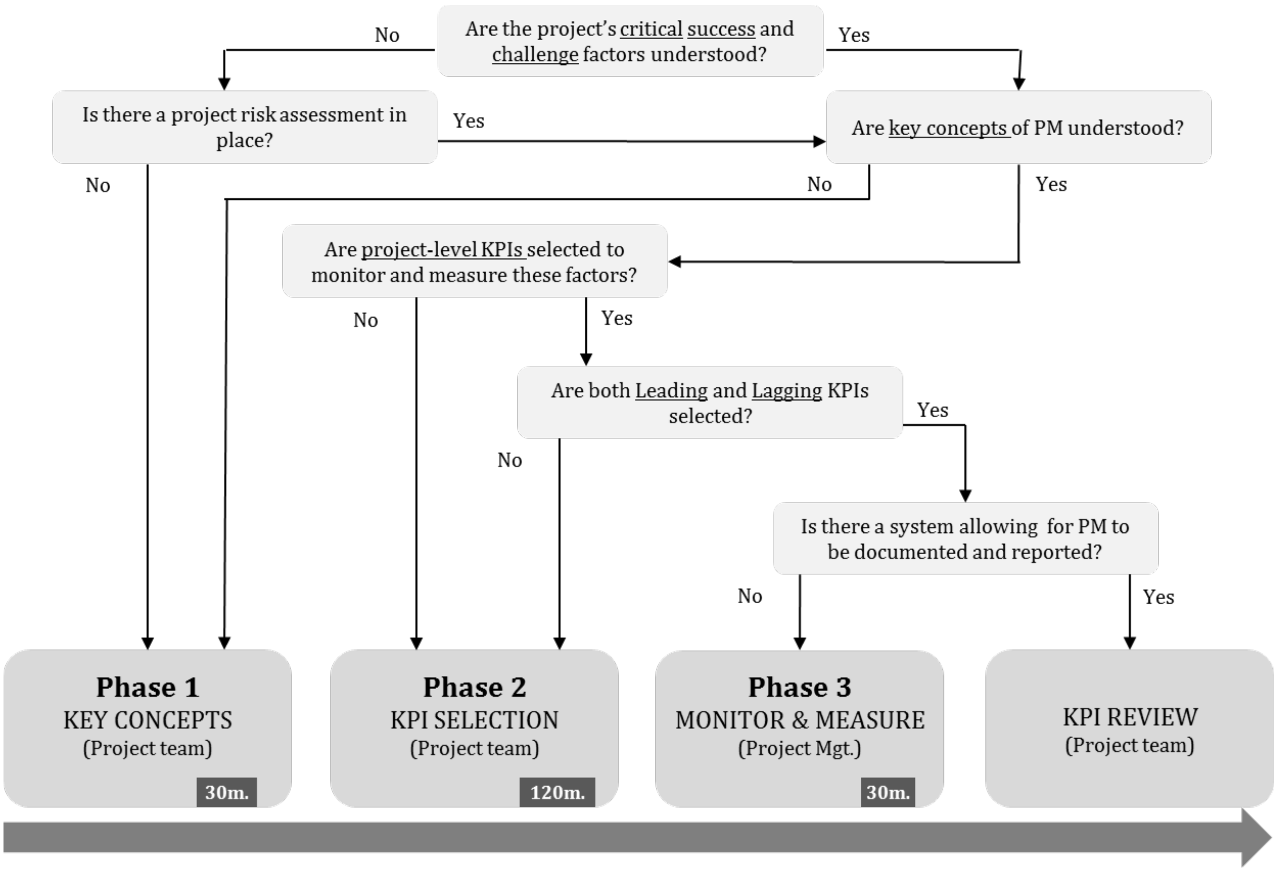

Figure 5-3 Assessment of conditions prior to implementing the KPI selection toolkit

5.4 Study three: Evaluation of support method

The objective of study three was to evaluate the impact of the proposed support method in relation to the verification for supporting: (1) the identification of factors influencing success in GPD; (2) the selection and documentation of leading and lagging KPIs to inform decision making along the process; and (3) the development of precautionary strategies to avoid factors influencing success as a result of the support method, addressing research question 4 in Table 3-1 see Chapter 3 section 3.2. For the overall description of the methods employed in Study three, the experimental setup and the participants see Chapter 3 section 3.7, or paper VII.

5.4.1. Evaluation of support method: Implementation of the KPI selection toolkit

This section presents the results from the four hour workshop held at Company C for the implementation of the KPI selection toolkit.

5.4.1.1. Phase 1

The key concepts in the toolkit were presented to the project team without the need for additional explanation towards these.

The total time spent during Phase 1 in the toolkit was 20 minutes.

5.4.1.2. Phase 2

Key motivations (desired outcome) and challenges (factors influencing this outcome) for the project were identified and mapped to the Fishbone diagram illustrated in Figure 5-4. During this process, examples of key motivations and challenges presented in the toolkit helped steer discussions within the project team. The project team referred to the business-level KPIs that were standard for PD projects at the company, namely: *Development cost*; *Project lead-time*; and *Customer satisfaction* in order to identify the desired outcomes for the project. Many factors influencing the success towards the desired outcomes were identified such as *Availability of resources*, *Communication*, *Documentation*, *etc*. In relation to each of these factors, key project-level issues such as *Knowledge and experience within the team*, *Project prioritisation*, *etc.* were identified and mapped to the smaller branches in the Fishbone diagram.

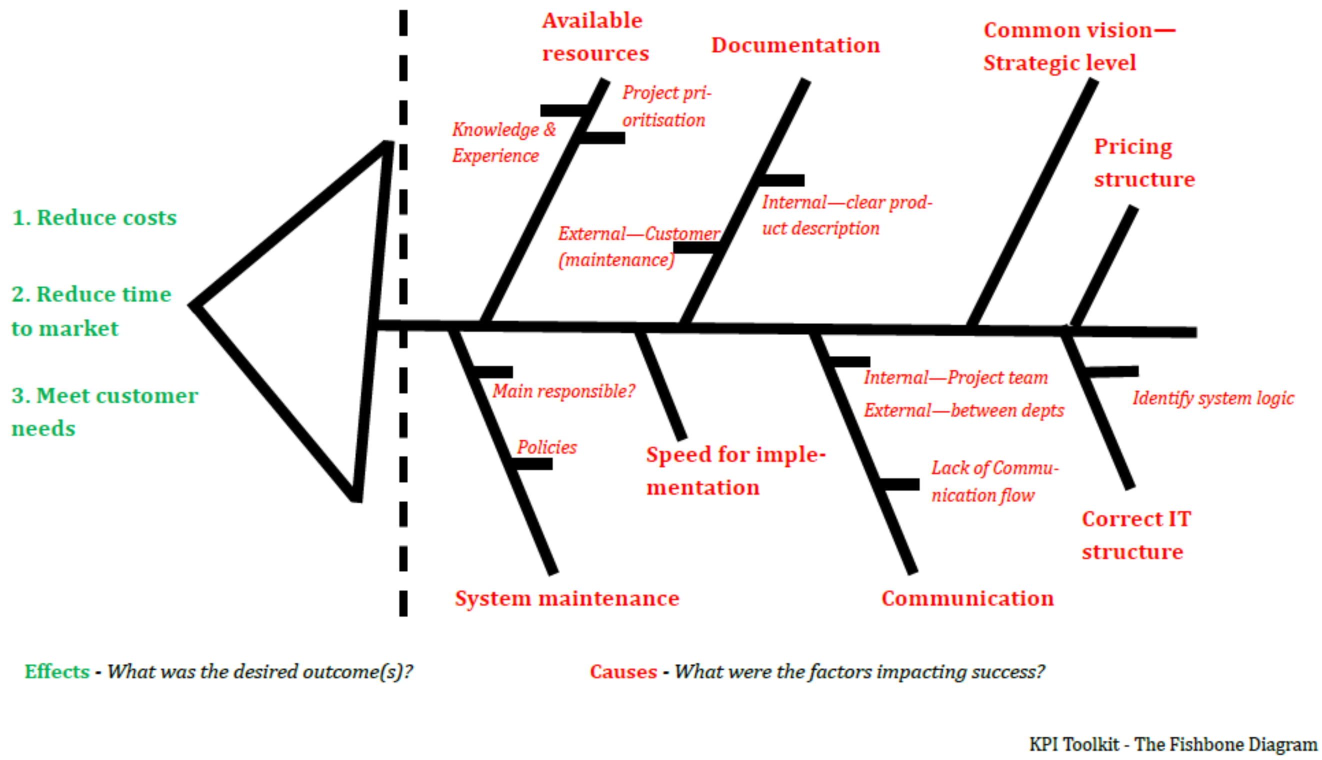

Figure 5-4 Phase 2: Key motivations and challenges mapped to the Fishbone diagram (Round one)

The following step was to prioritise the key factors identified according to their importance for the project. This was completed based on the prior knowledge and experience with similar projects within the project team and resulted in a round-the-table vote of the factors they perceived to have the highest influence on success. *Reduced costs* and a *Reduced time to market* were the most important outcomes for the project and *Communication* (both internal and external from the project team) was highlighted as the most important factor influencing success towards these outcomes (Figure 5-5). Strategies and activities were planned to minimise the impact of the challenges highlighted and achieve success towards the desired outcome. For example, for communication issues internally in the project team a key strategy was to set up regular meetings throughout the project, which included key project stakeholders. For communication issues externally from the project team i.e. across functions at Company C, a key strategy was to create a document where the level of acceptance across the different functions towards the software being developed would be monitored.

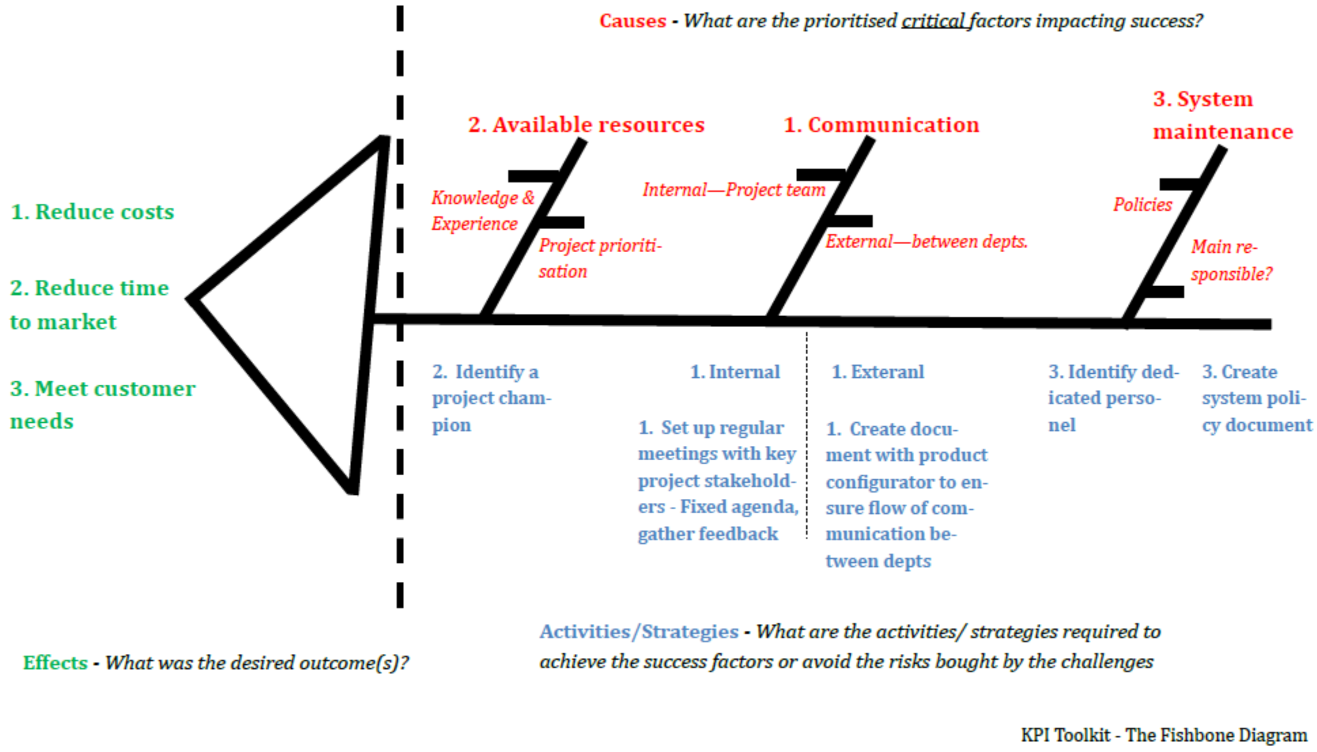

Figure 5-5 Phase 2: Prioritisation of key factors and planned strategies as a result of these mapped to the Fishbone diagram (Round two)

The following KPIs were developed within the project team to monitor and measure the key factors identified:

- Communication issues internally was considered a key factor that may result in project time delays and hence, the lagging KPI developed to measure this was *Development time.* To avoid communication issues internally, a high level of particiaption from key project stakeholders during planned project meetings was considered important to prevent such issues and hence, the *Level of particiaption* was developed as a leading KPI to monitor this during the project.
- Communication issues externally was considerd a key factor that may result in design rework and an increase in project costs and hecne, the lagging KPI developed to measure this was *Development cost.* To prevent communication issues externally, the interests across the different functions required aligning in relation to the development of the software and hence, the leading KPI *Alignment of interests* was developed to monitor this during the project.

The planned strategies and KPIs developed were then mapped according to the standard PD process followed at Company C, providing indication as to where along the process the strategies required implementing and the KPIs required monitoring and measuring. For example, it was considered important to set up regular project meetings involving key project stakeholders during the early stages of the project and to monitor the *Level of particiaption* for each of these.

The total time spent during Phase 2 of the toolkit was 120 minutes.

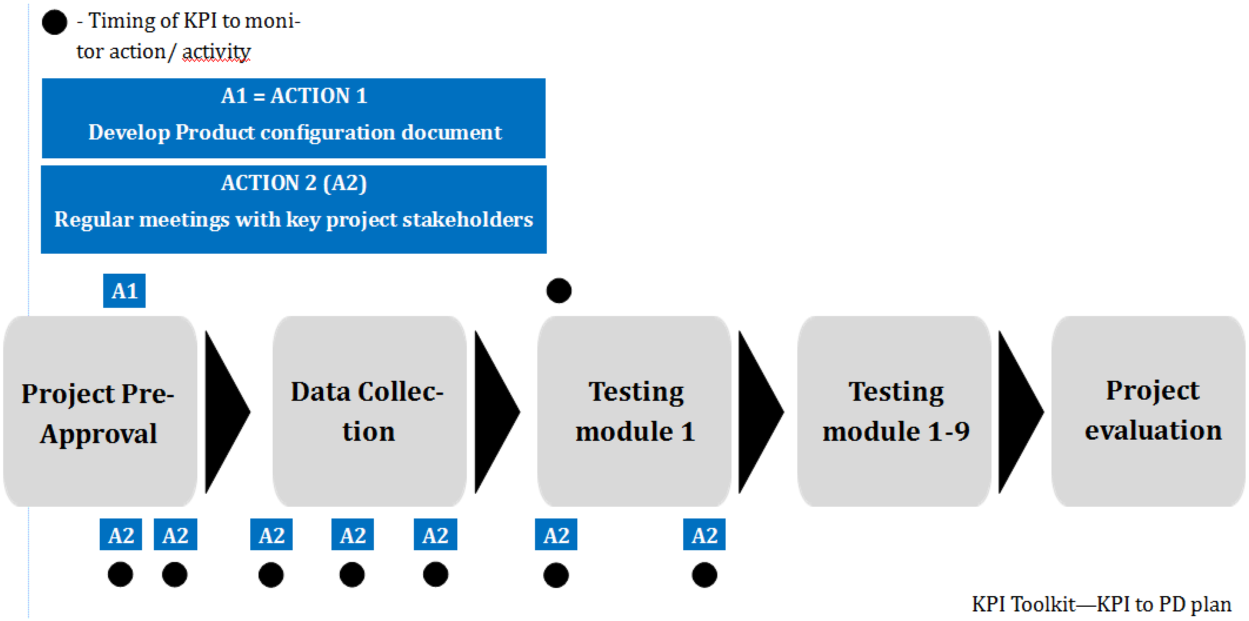

Figure 5-6 Phase 2: Planned strategies and KPIs mapped to the standard PD process at the company

5.4.1.3. Phase 3

Each of the developed KPIs were documented according to the fields in the KPI template by the project manager with an example of this illustrated in Figure 5-7 for the KPI *Level of participation*. Due to time restrictions, it was not possible to identify the key targets for the KPI and hence, the KPI one pager was not completed during the workshop. Documentation to support the completion of this was provided to the project manager (refer to Appendix 4 for KPI one pager documentation).

The total time spent during Phase 3 of the toolkit was 30 minutes.

Measure	***Communication within project team***
Critical influence factor related to:	*Communication/ Lack of common vision - within the project team.*
Desired outcome(s) related to:	*Reduce costs, Reduce time to market.*
Purpose:	*Ensure communication during project completion with key project stakeholders to avoid project time delays*
KPI:	*Level of participation (of key stakeholders during project meetings)*
Formula:	*Count the number of key participants during pre-arranged meetings (see notes) Vs the number of invited key participants.*
Responsible:	[redacted]
Target:	*TBC*
Min:	*TBC*
Max:	*TBC*
Target per week/ month:	*TBC*
Freq. of measurement:	*All pre-arranged project meetings*
Stage during PD:	*High frequency during project planning stages and data collection. Less frequent during testing and refinement stages.*
KPI classification:	*Leading KPI*
Lagging/Leading KPI related to:	*Development time*
Notes	***ACTION:*** *Set up regular meetings with key project stakeholders during project completion. The meeting should be more frequent during the early stages of the project* *Who should be involved in the project meetings?*

KPI Toolkit - The KPI template

Figure 5-7 Phase 3: Example of documented KPI according to the KPI template

5.4.2. Evaluation of support method: Preliminary evaluation of the KPI selection toolkit

In the following sections, the impact of the KPI selection toolkit is presented in relation to the verification for supporting: (1) the identification of factors influencing success of the development project; (2) the selection and documentation of leading and lagging KPIs to inform decision making along the process; and (3) the development of precautionary strategies to avoid factors influencing success. The results from the surveys and interviews are structured in accordance to the key principles for evaluation highlighted in Chapter 3 section 3.7.3 (refer to Appendix 4 for specific questions in the surveys and interviews).

5.4.2.1. Reaction: the usefulness and applicability of the toolkit

Figure 5-8 illustrates the reaction of participants towards the toolkit in relation to the applicability and usefulness of the method. The majority of participants found the toolkit to be 'Very' useful and applicable within their work environment. However, evaluating the reaction of participants towards the toolkit does not provide a measurement of any learning that took place as a result of the toolkit and hence, the next section addresses this.

5.4.2.2. Learning: the increased understanding towards key concepts for performance measurement

Learning was evaluated in relation to the participants' level of agreement towards the following statements both before and after the toolkit was implemented:

1. Critical steps required for selecting KPIs are understood (results illustrated in Figure 5-9)
2. The difference between leading and lagging KPIs is understood (results illustrated in Figure 5-10).

Figure 5-9 and Figure 5-10 illustrate that participants experienced an increase in understanding as a result of the toolkit towards: (1) the critical steps required for selecting KPIs; and (2) the difference between leading and lagging KPIs, which implies that Phase 1 in the toolkit supports this learning.

5.4.2.3. Results: the difference between KPIs selected prior to and post implementation of the toolkit

Due to the time constraints of this research project, the effect that the selected KPIs had on overall project performance could not be observed and is discussed further in Chapter 3 section 3.7.5. However, by identifying KPIs selected both before and after the implementation of the KPI selection toolkit, an evaluation could be made based on the influence that the structured approach for selecting KPIs had on the final KPIs selected i.e. evaluate the quality of the KPIs before and after the approach.

KPIs stated by participants for measuring performance in the development project at Company C prior to implementing the toolkit included: *Cost to run project*, *Performance* and *Quality*. The KPIs stated as a result of the toolkit included: *Level of acceptance* and *Alignment of interests* (leading KPIs) and *Development time* and *Development cost* (lagging KPIs). This implies that the structured approach to selecting KPIs in the toolkit influenced the KPIs selected and encouraged the selection of both leading and lagging KPIs, which was a key requirement for the toolkit highlighted in section 5.2.

Furthermore, Neely *et al.*, [2000] propose six desirable characteristics for designing KPIs see Chapter 2 section 2.3.5. These are presented below in relation to how the KPI selection toolkit fulfilled these characteristics:

1. Indicators should be derived from the company's strategy.

During phase 2, high-level motivations and challenges were identified within the project team, which were related to the overall business strategy for conducting the project (see Figure 5-4). Following this, strategies and activities were planned to minimise the impact of the challenges highlighted and achieve success towards the desired outcome (Figure 5-6). The KPIs were derived based on this process and hence, were related to the business strategy.

2. The purpose of the indicator must be made explicit.

During phase 3, the completion of the KPI template (see Figure 5-7) ensured that the purpose for the KPIs was understood.

3. Data collection and methods of calculating performance must be clear.

During phase 3, the completion of the KPI template ensured the formula for calculating the KPI was understood. However, due to time restrictions at the company, it was not possible to document the minimum and maximum targets for the KPI.

4. All stakeholders must be involved in the selection of the indicators.

The key members of the project team actively participated during the development of the KPIs.

5. The indicator should take account of the organisation.

The diversity of the participants during the KPI selection workshop such as a sales director, R&D director, global product manager, etc (see Table 3-17) provided the basis for discussions that considered different functions at the company. Furthermore, the steps followed in phase 2 provided a structured approach for these discussions.

6. The indicators should change as circumstances change.

Mapping the KPIs to the company's PD process during phase 2 ensured the frequency for measurement of the KPIs changed according to the stages in the PD process.

5.4.2.4. Validation: the improvements required to the toolkit

Figure 5-11 indicates that participants either 'Strongly agreed' or 'Agreed' that the toolkit:

1. Provided a structured approach for selecting KPIs
2. Supported the selection of both leading and lagging KPIs.

The majority of participants did not provide indication towards how the toolkit could be improved. However, the project manager (INC4 in Table 3-17) stated that it would have been beneficial to spend more time discussing the lagging and leading KPIs selected for the project. The lack of understanding towards lagging and leading KPIs in industry was further highlighted during the descriptive study I phase see Chapter 4 section 4.2.2 despite these being established terms in literature [Kaplan & Norton, 1996]. When developing the KPI selection toolkit, the estimated time for completing Phase 3 was inadequate when implementing the toolkit at Company C and as a result, all activities were not completed during this phase see Chapter 5 section 5.4.1.3. Based on this and the feedback from the project manager, the following improvements were considered for the toolkit:

- The time for completing Phase 3 required extending from 30 minutes to 90 minutes in the toolkit to provide sufficient time for completing the KPI template and KPI one pager and hence, provides increased time for discussing the lagging and leading KPIs selected.

5.4.2.5. Behaviour: the impact of the toolkit on everyday tasks and activities

The two interviews conducted with participants, five months after the toolkit was implemented at company C, enabled the evaluation towards the behavioural impact of the toolkit.

During the interviews, it was discovered that the start date for the development project had been delayed at Company C and therefore the selected KPIs had not yet been implemented. However, the planned strategies as a result of the toolkit were in place see Chapter 5 section 5.4.1.2, with the KPIs expected to be implemented once the project began. The interviewees found that adopting the Fishbone diagram to identify critical factors influencing the success of the project during Phase 2 of the toolkit supported in aligning the common vision within the project team, which is often a challenge experienced in non-collocated projects see Chapter 4 section 4.2.2.2. In addition, by highlighting the influence factors that supported the formulation of the KPIs, the interviewees felt this increased the commitment towards accepting and using the KPIs within the project team, which was a key challenge highlighted during the descriptive study I stage see Chapter 4 section 4.2.1. The knowledge gained during phase 2 of the toolkit, in particular the increased understanding of leading and lagging KPIs, had been used indirectly within the company and passed on to other projects. During the evaluation of the toolkit an interviewee stated:

"We have used the mind-set of not only measuring the end result but also how to improve the process as we go along… it really has impacted a lot on the way we approach and discuss KPIs, and also the structured way to identify and categorise has been very helpful". Project manager, Company C (INC4 in Table 3-17).

In sum, the results from the implementation and evaluation imply that the KPI selection toolkit supports the following:

- The identification and prioritisation of key factors influencing success supports the development of precautionary strategies to avoid the impact of these. Furthermore, this phase in the toolkit supports in creating a common vision within the project team, which is a key challenge identified in GPD projects see Chapter 4 section 4.2.2 and confirmed in literature [Hansen & Ahmed-Kristensen, 2012].
- The selection and documentation of: (1) leading KPIs - to monitor factors influencing the success of the project along the process; and (2) lagging KPIs – to measure the performance towards the outcome of the project.

- The structured approach encourages the documentation of the process and hence, enables key knowledge and experience to be transferred to future projects.

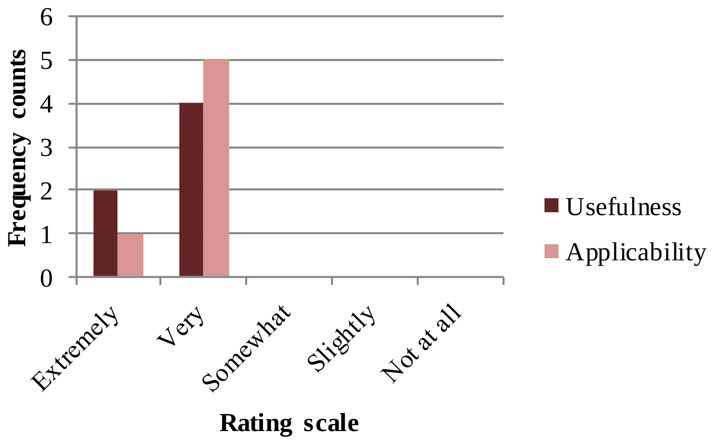

Figure 5-8 Reaction: the usefulness and applicability of the support method

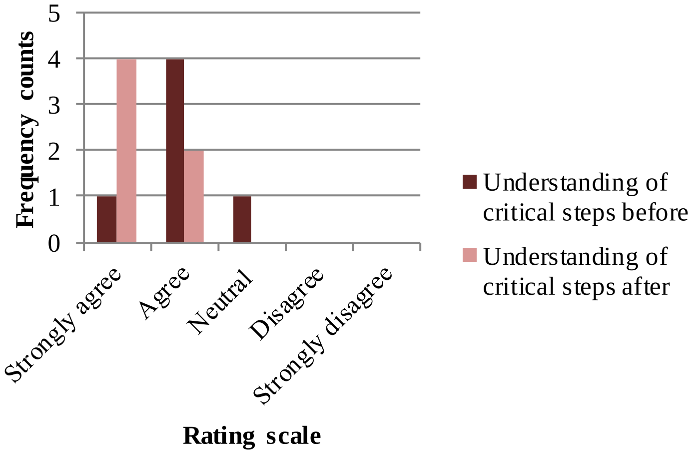

Figure 5-9 Learning: the understanding towards the critical steps required for selecting KPIs before and after the workshop

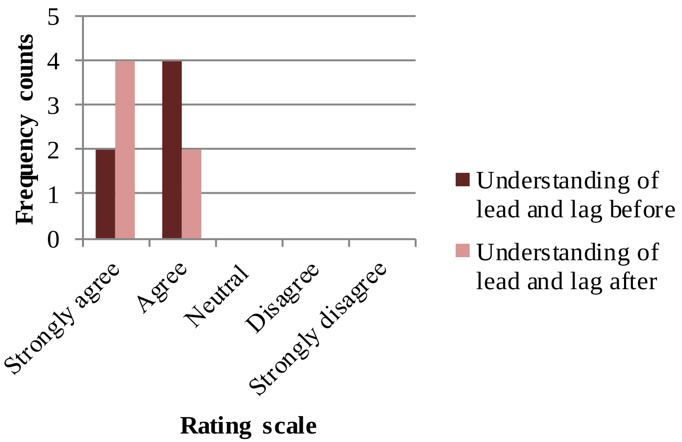

Figure 5-10 Learning: the understanding towards the difference between leading and lagging KPIs before and after the workshop

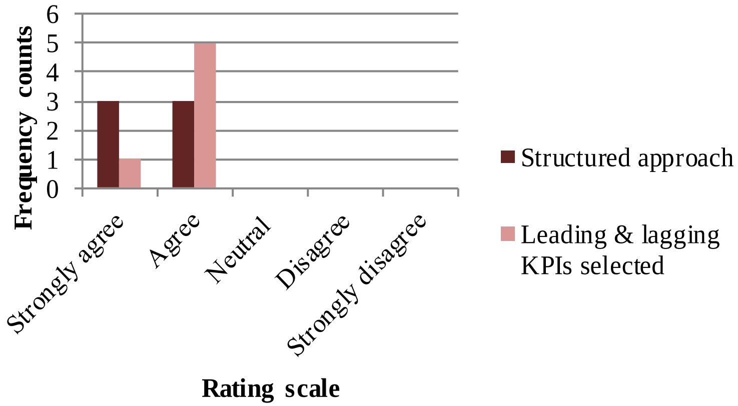

Figure 5-11 Validation: verification that support method provided a structured approach for selecting KPIs and supported selection of leading and lagging KPIs

5.5. Conclusions

The support method, namely: The KPI selection toolkit was developed based on key findings described in Chapter 4 section 4.4. Key elements of the support method provide support towards the identification of key factors influencing success in GPD projects and provides a structured approach for the selection and documentation of KPIs to monitor and measure these. The support method builds on key concepts in the field of GPD [Hansen & Ahmed-Kristensen, 2012] and performance measurement [Kaplan & Norton, 1996, Neely *et al.*, 2000] and key findings from the descriptive study I phase (see Chapter 4 section 4.4) and hence, advances knowledge by:

- Introducing a shift from traditional goal-oriented approaches to the selection of KPIs to include a challenge-oriented approach, which supports the selection of both lagging and leading KPIs to provide the necessary feedback to develop precautionary strategies and hence, minimise the risk of factors influencing success along the process.

A third study with a large Danish manufacturing company during a software development project was conducted and focussed on the implementation and evaluation of the proposed support method. Based on this and considering the key issues for the development of the support method, the following key impacts on industry as a result of the support method were observed:

- The identification and prioritisation of key factors influencing success supports the development of precautionary strategies to avoid the impact of these. Furthermore, this phase in the support method supports in creating a common vision within the project team, which is a key challenge identified in GPD projects.
- The selection and documentation of: (1) leading KPIs - to monitor factors influencing the success of the project along the process; and (2) lagging KPIs – to measure the performance towards the outcome of the project
- The structured approach encourages the documentation of the process and hence, enables key knowledge and experience to be transferred to future projects.

Given the time restrictions of this research project it was not possible to implement and evaluate the support method in the context of an actual ongoing GPD project and therefore, caution should be taken when generalising the results within a global context. Future studies as a result of this are described in more detail in Chapter 6 section 6.4.

Chapter 6 Conclusions

This chapter presents the main conclusions drawn from this research project including the literature review, the main findings from the empirical studies and the proposed method of support. Suggestions for further work are presented in section 6.5.

This thesis is an article-based thesis with a total of seven papers written during the research project (refer to Appendix 5 for the seven papers). Five papers were published in the proceedings of various design and operations management conferences and two papers are, at the time of writing this thesis, at different stages of review within journals of operations management.

The research in this project was conducted in close collaboration with Danish manufacturing companies that globalised parts of their product development process to understand: the current practice for performance measurement in global product development; and how this can be supported to allow for informed decision making along the process. Three empirical studies were conducted that contributed to the different stages of this research project and are summarised here according to the research questions the studies addressed.

<u>Research question 1:</u> What is the current practice for measuring performance in conventional and global product development projects?

- A literature review together with Study one: Exploratory study, including two cross-company surveys with a total of 44 Danish manufacturing companies, were conducted to address this.

<u>Research question 2:</u> How are key performance indicators used to monitor factors influencing success in global product development projects?

- Study two: Multiple case studies, was conducted with two large Danish manufacturing companies, including 23 interviews, 34 direct observations and the analysis of documents, which provided the in-depth understanding to address this.

<u>Research question 3:</u> How to support the selection of key performance indicators that provide project management with timely feedback on performance?

- Based upon the findings from the previous studies, the “KPI selection toolkit” was developed to support the identification of key factors influencing success in global product development projects and provide a structured approach for the selection and documentation of key performance indicators to monitor and measure these.

Research question 4: How does the proposed method support the process of selecting key performance indicators in global product development projects?

- Study three: Evaluation of support method was conducted with a large Danish manufacturing company to evaluate the impact of the “KPI selection toolkit” in industry.

The empirical studies lead to the advancement of knowledge toward the current practice for performance measurement in global product development and how this can be supported to allow for informed decision making along the process.

The main findings from the literature review and the empirical studies are presented in the following sections according to the research questions they address.

6.1 The current practice for performance measurement in conventional and global product development projects

The main findings from the literature review and exploratory study are presented here, which address research question one in this research project. The objectives for research question one focussed on identifying the current practice for performance measurement, with a focus on the use of key performance indicators (KPIs), and their applicability within the context of global product development (GPD).

Research on performance measurement in conventional product development (PD) is relatively underdeveloped and is increasingly the case when parts of PD are globally distributed. To investigate this, the research has reviewed relevant literature in the field of engineering design and operations management. In engineering design, key factors influencing success in conventional PD and GPD were reviewed together with management approaches to support this transition. In operations management, key concepts for performance measurement, in particular the selection and application of KPIs in business processes in general, were reviewed together with management tools to support this.

In conventional PD, success at the project-level was found to be multifaceted and dependent on the environment in which it operates and the many different stakeholders involved during the process. The need for additional dimensions when determining success to those in the traditional Iron

Triangle, namely; time, cost, and quality has been highlighted for assessing the less tangible outputs of PD activities [Wang, *et al.*, 2010, Toor & Ogunlana, 2010, Snider *et al.*, 2016]. The large number of factors identified that influence success in PD projects (Table 2-1) further indicates the multidimensionality of this topic. Identifying factors that *influence* success is useful for developing preventative measures for researchers and practitioners [Badke-Schaub & Frankenberger, 1999] and hence; can support the management and monitoring of PD projects.

Globalising parts of PD adds further complexity to the PD environment and managing culturally diverse and geographically dispersed engineering teams during GPD accentuates the many factors that influence success typically found in conventional PD [Hansen & Ahmed-Kristensen, 2011, Anderson & Parker, 2012]. A number of studies investigate the high-level challenges companies encounter during GPD [Eppinger & Chitkara, 2009, Hansen & Ahmed-Kristensen, 2011, Kalyandurg & Akhilesh, 2012] and this area of research is beginning to mature. However, these studies typically consist of interviews or observations of short design sessions and do not provide the in-depth insight required to investigate the impact that such challenges may have on GPD at the project-level. Such understanding can support researchers and practitioners to develop precautionary measures and hence, avoid the learning-by-doing approach to managing GPD projects that has previously been observed in several industrial case studies [Barthelemy, 2003, Hansen & Ahmed-Kristensen, 2011].

The need for developing KPIs to support the identification and avoidance of problems as they arise and hence, support decision making in GPD has been highlighted [Christodoulou *et al.*, 2007, Hansen & Ahmed-Kristensen, 2012]. However, to the authors' knowledge there are few studies that investigate this in the context of GPD. A criticism towards KPIs applied in conventional PD projects is they are lagging in nature and typically focus on measuring the outcome of a process [Driva, 1997, Tatikonda, 2007, Rhodes *et al.*, 2009]. Although such indicators are useful in showing history and progress of an organisation's efforts, lagging indicators fail to provide information for predictive purposes, and hence do not allow management to take action before problems arise. Given the additional challenges in managing geographically dispersed engineering teams in GPD projects, the application of lagging KPIs alone may be inadequate to inform management of where to make adjustments to avoid deviations along the process. The importance of developing KPIs according to factors that influence the success of a process (leading KPIs), rather than those that solely measure the outcome of a process (lagging KPIs), has been highlighted [Kaplan & Norton, 1996, Neely *et al.*, 2005, Rhodes *et al*., 2009].

The literature review highlighted that research towards performance measurement has focussed on business processes in general and there exists a need to further understand the current practice for performance measurement in GPD at the project-level.

A need was identified to understand the key factors influencing success in GPD at the project-level and the current practice for the selection and application of KPIs. This understanding could provide the basis for the development of a method to support performance measurement in GPD and allow for informed decision making along the process.

6.1.1 Key motivations and challenges in global product development and the key performance indicators for measuring performance

Study one: Exploratory study provided an understanding towards the key motivations and challenges in GPD and KPIs used for measuring performance and hence, enabled the investigation of the applicability of KPIs in the context of GPD. The main findings highlight that leading KPIs, as oppose to lagging KPIs typically used in conventional PD, are required in GPD to monitor the less tangible challenges that influence the success along the process and hence, provide timely feedback to avoid deviations during GPD. However, participants experienced difficulties when stating KPIs to monitor the key challenges in GPD, which implies that support is required for this process. The goal-oriented approach resulted in KPIs that focussed on measuring the more tangible outcomes and were lagging in nature, which have been described to provide a time-delayed look on performance and could be categorised according to common KPIs in conventional PD such as development time, development cost and customer satisfaction.

- The findings from Study one: Exploratory study contribute to the advancement of knowledge towards the selection of KPIs in PD when engineering teams are globally dispersed, which builds on studies that investigate this in conventional PD that typically consists of local, cross-functional members [Griffin & Page, 1996, O’Donnell & Duffy, 2002]. Furthermore, Survey II identifies KPIs selected as a result of key challenges in comparison to common approaches in literature that identify KPIs that are goal-oriented.

A more in-depth understanding towards the key motivations and challenges encountered in GPD and the influence these have at a project-level was required. Furthermore, the selection and application of KPIs in GPD, in particular in relation to those selected and used for monitoring the challenges in GPD at the project-level, was required to fully address the research questions in this research project.

6.2 The key factors influencing success and the selection and application of key performance indicators in global product development projects

The main findings from the multiple case studies are presented here, which primarily address research question two and partially question one in this research project. The objectives for research question two focussed on identifying the key factors influencing success in GPD and understanding the cause-effect relationship of these factors at the project-level. In addition, objectives included elucidating the current practice for selecting KPIs and understanding how KPIs are used to monitor challenges and motivations in GPD projects.

The multiple case studies provided the in-depth understanding to investigate the key cause-effect relationship of factors influencing success at the project-level in GPD. The main findings highlight how key challenges encountered at Company A and Company B with the global R&D resulted in a number of management approaches to mitigate the risk of failure in the observed GPD projects. However, the management approaches resulted in a lack of common vision in the GPD project team as the lack of balance between the level of responsibility and control negatively influenced the motivation of the engineers at global R&D facilities. When managing engineering teams that are globally dispersed, the importance of ensuring clarity and understanding towards the tasks in the PD process itself, rather than simply distributing less complex tasks for the global R&D, is important.

- The findings from Study two: Multiple case studies contribute to the advancement of knowledge by providing unique insight towards key cause-effect relationships of the factors influencing the success in GPD, which is seldom addressed in literature with multiple longitudinal case studies in GPD at the project-level, providing the basis for researchers and practitioners to develop practical tools in GPD.

Furthermore, the multiple case studies provided the in-depth understanding to investigate the selection and application of KPIs in GPD at the project-level. The main findings highlight that a lack of a structured approach for the selection of KPIs resulted in lagging KPIs being selected in accordance with high level KPIs at the companies in the observed GPD projects. The lagging KPIs did not provide necessary feedback to avoid challenges such as a lack of common vision that influenced success along the process at the project-level. In addition, the findings highlight a lack of understanding towards leading and lagging KPIs in industry, despite these concepts being established in the literature.

- The findings from Study two: Multiple case studies contribute to the advancement of knowledge by building on previous studies in the field of GPD, which highlight the importance of selecting KPIs to support the identification and avoidance of problems as they arise [Christodoulou *et al.*, 2007, Hansen & Ahmed-Kristensen, 2012], and develops an understanding towards the selection and application of KPIs in accordance with key challenges encountered in GPD at the project-level.

Based on the results from the exploratory study and multiple cases studies, a need was identified to support the identification of key factors influencing success in GPD and provide a structured approach for the selection and documentation of KPIs to monitor and measure these. Such approach could provide the necessary feedback to enable adjustments along the process and avoid the impacts on success.

6.3 Development of the KPI selection toolkit

A method of support was developed based upon the main findings from the exploratory study and multiple case studies and addresses research question three in this research project and is presented in section 6.3.1. The objectives for research question three were to develop a method that supports: the identification and prioritisation of critical factors influencing success in GPD projects; and the selection and documentation of leading and lagging KPIs to monitor and measure these.

6.3.1 The KPI selection toolkit

The KPI selection toolkit was developed based upon the need identified in Study one: Exploratory study and Study two: Multiple case studies to provide a structured approach for the development and selection of both leading and lagging KPIs at the project-level for monitoring the key challenges that influence success in GPD and hence, support the identification of deviations along the process. The KPI selection toolkit was developed to support project managers in manufacturing companies to execute a KPI selection workshop in PD projects consisting of globally distributed engineering teams. The toolkit consists of the following key steps which aim to:

1. Develop an understanding towards the relationship between leading and lagging KPIs to ensure the purpose of the selected KPIs is understood and to gain commitment within the GPD project team.
2. Support the identification of key factors influencing success in GPD projects to inform project management of where along the process to set up precautionary strategies. Key challenges, motivations and strategies identified during the exploratory study and multiple case studies are utilised to prompt participants during this phase.
3. Provide a structured approach for the selection and documentation of both leading and lagging KPIs to monitor and measure the key influence factors to support decision making and identify deviations along the process. KPIs identified during the exploratory study and multiple case studies are used to support this phase.

In accordance with design requirements raised as a result of the findings in the literature review and Study one: Exploratory study and Study two: Multiple case studies, the main contribution of the support method were:

- The method of support introduces a shift from traditional goal-oriented approaches to the selection of KPIs to include a challenge-oriented approach, which supports the selection of both leading and lagging KPIs at the project-level in GPD to provide the necessary feedback to develop precautionary strategies that minimise the risk of factors influencing success along the process.

6.4 Evaluation of the KPI selection toolkit

The impact of the support method in industry was evaluated in a third company case to address research question four in this research project. The objectives for research question four were to evaluate how the proposed method supports: the selection of both leading and lagging KPIs in GPD; and the early identification of critical factors influencing success in GPD projects to minimise the risk towards these.

To evaluate the impact of the KPI selection toolkit in industry, a third study was conducted with a large Danish manufacturing company during a collocated development project. Initial results suggest that the toolkit supported the identification of key factors influencing success and the selection and documentation of leading and lagging KPIs to measure and monitor these and hence, the steps in the toolkit were validated. However, it was not possible to fully document the KPIs due to inadequate time allocated for implementing the toolkit. Furthermore, the project manager suggested the toolkit could be improved by spending more time in discussing the relationship between the selected leading and lagging KPIs. As a result, the time allocated for the documentation of the selected KPIs was increased from 30 to 90 minutes to allow sufficient time for documenting the KPIs and to further develop the understanding of the relationship between the leading and lagging KPIs selected with the project manager.

As a result of the process followed in the KPI selection toolkit, a number of precautionary strategies were implemented at the company to minimise the risks of the identified key influence factors. Furthermore, identifying key factors, prior to the selection of KPIs, proved a valuable element of the toolkit and supported in creating a common vision within the project team, which was a key challenge identified in GPD projects. In general, the steps in the toolkit increased the level of understanding towards leading and lagging KPIs within the project team, which was used in future projects when developing KPIs at the company. By documenting the steps in the toolkit, key knowledge and experience could be transferred to future projects.

- The findings from Study three: Evaluation of the support method exemplifies how the KPI selection toolkit is a valuable process to identify key factors influencing success and develop precautionary strategies, rather than simply a framework to support the selection of KPIs. Although the support method was developed for the application in GPD projects, the results from the evaluation suggest that the steps in the support method are also valuable in conventional development projects that typically consist of local, cross-functional team members.

The research has contributed to the advancement of knowledge towards the current practice of performance measurement in GPD, in relation to the selection and application of KPIs, and developed an understanding towards key factors that influence the success at the project-level, which is seldom addressed in literature in the context of GPD. A method to support the identification of key factors influencing success in GPD projects and provide a structured approach for the selection and documentation of KPIs to monitor and measure these has been developed.

The research has been carried out in close collaboration in industry and differs from previous studies in that the findings have been used to develop a method to support project managers in manufacturing companies during the execution of PD projects with globally distributed teams, rather than with local, cross-functional teams typically found in conventional PD. The total time for data collection and analysis during this research amounted to 1088 hours (or 136 days) and is broken down in Table 6-1. Many issues need to be considered when carrying out multiple case studies in industry, e.g. the time required to identify and set up the company cases. Such issues added to the time involved in data collection and analysis.

Stage of overall research methodology	Study	No. of hours	No. of days	No. of participants
Descriptive study I	Exploratory study	136	17 days	44
	Multiple case studies	896	112 days	23
Descriptive study II	Evaluation of support method	56	7 days	6
	Total	1088	136 days	73

Table 6-1 Breakdown of time spent on data collection and analysis

The research has found that when managing the transition from conventional to globally distributed PD, tasks and activities are decomposed into globally distributed work packages to enable distributed engineering teams to work autonomously. However, a lack of balance between the level of responsibility and control during the completion of such work packages can result in challenges such as a lack of common vision in the GPD team that influence the success at the project-level. To support the early identification of such challenges and hence, develop necessary precautionary strategies a method of support was developed to identify key factors influencing success along the process and develop both leading and lagging KPIs to measure performance in GPD projects.

6.5 Further work

The research has begun to understand the current practice for performance measurement in GPD projects in Danish manufacturing companies and how this can be supported to allow for informed decision making along the process. The following areas have been identified for further research:

- This research is one of very few longitudinal observational studies in industry of real tasks and activities in the context of globally distributed engineering design projects. There is a requirement for additional studies of this type that enable identified influence factors to be traced back to their initial causes in GPD and hence, build a depository of knowledge that provides indication to researchers and practitioners of where along the process preventative strategies require developing.
- This research investigated the selection and application of KPIs to measure performance in PD projects consisting of globally dispersed and culturally diverse engineering teams. A

comparative study in conventional PD projects consisting of local, cross-functional members would be useful to identify the key differences towards how management approach performance measurement in both conventional and globally distributed PD projects.

- The KPI selection toolkit was evaluated in a software development project where the main project team was collocated. There is a requirement for the toolkit to be evaluated in a PD project where parts of the process are globally distributed to understand the impact of the toolkit in this context.
- To implement the KPI selection toolkit, a considerable amount of time is required for the preparation and facilitation of the toolkit from the researcher. A guidebook aimed at practitioners to support the implementation of the toolkit would help reduce the requirement for facilitation and increase the applicability of the toolkit in industry.

Glossary

The following terms and definitions are used in this thesis.

Term	Explanation	Reference
Activity	A subdivision of the product development process that relates to an individual's problem solving process and reoccurs several times for every product element	Blessing and Chakrabarti [2009]
Business-level	A logical element or segment of a company (such as accounting, production, marketing) representing a specific business function, and a definite place on the organizational chart, under the domain of a manager. Also called department, division, or a functional area.	The Business Dictionary [2016]
Conventional product development	• The team is largely co-located with similar cultural backgrounds. • Uses a combination of digital product development tools and conventional paper-based processes for engineering	McDonough *et al.*, [2001], Eppinger and Chitkara [2009]
Cumulative percentage	A calculation of the percentage of the cumulative frequency of the observations	Wilkinson [2006]
Domain	The particular subject matter of interest within some context	Ahmed-Kristensen [2001]
Engineering team	The group of design engineers responsible for the development of the product.	Hales [1987]
Global product development	• The globalisation of tasks and activities throughout the product development process, from the early concept development stage and detail design through to the final testing of prototypes ready for production. • The team is distributed across multiple geographic locations and are culturally different. • Uses an entirely digital product development process to facilitate distributed, collaborative engineering features a highly distributed, networked development process facilitated by a fully digital product development system.	McDonough *et al.*, [2001], Eppinger and Chitkara [2009], Hansen and Ahmed-Kristensen [2012]
Key factor influencing success	Critical factors identified as important for influencing the success of product development projects	Hales [1987]
Key performance indicator	Quantifiable metrics that help measure the success of identified critical factors.	Gries and Restrepo [2011]

Lagging key performance indicator	Indicators that measure the output of past activity and typically consist of financial indicators. Customer satisfaction or employee attitudes are examples of lagging indicators and report how well the organisations strategy worked in the past period but provide little guidance on how to navigate to the future.	Kaplan and Norton [1996]
Leading key performance indicator	Indicators that measure the factors impacting a process and are drivers of performance. See Chapter 2 section 2.3.1 for an example of a leading indicator.	Kaplan and Norton [1996]
Offshoring	moving a task or a function to a facility owned by e.g. a Danish company, to a low cost country e.g. China, India.	Hansen and Ahmed-Kristensen [2012]
Outsourcing	Moving a task or function to a facility owned by a third party, often to a local company in a low cost country e.g. China, India.	Hansen and Ahmed-Kristensen [2012]
Performance measurement	Performance is defined as the effectiveness and efficiency of a process with the purpose of achieving a fixed objective or set of goals. The measurement of performance requires a balanced set of financial and non-financial key performance indicators, which are derived from business-level strategy.	O'Donnell and Duffy [2005], Neely *et al.*,[2000]
Product development process	The development process for a product can be described as having six stages: 1. Planning 2. Concept development 3. System-level design 4. Detail design 5. Testing and refinement 6. Production ramp-up.	Ulrich and Eppinger [2011]
Process	Sequence of interdependent and linked procedures which, at every stage, consume one or more resources (employee time, energy, machines, money) to convert inputs (data, material, parts, etc.) into outputs. These outputs then serve as inputs for the next stage until a known goal or end result is reached.	The Business Dictionary [2016]
Project	A planned set of interrelated activities in the product development process to be executed over a fixed time period and within a certain cost and other limitations.	The Business Dictionary [2016]

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Appendix 1 Key performance indicators in conventional product development

Griffin and Page [1993] identified a total of seventy five performance measures, used by both practitioners and researchers, for the measurement of success and failure in conventional PD. The KPIs were obtained independently from literature and an empirical study. The KPIs were grouped according high-level performance dimensions, namely: Customer acceptance; Financial performance; Product-level performance; Firm-level performance; and Program-level performance. The KPIs identified are presented in the table below:

CUSTOMER-ACCEPTANCE MEASURES	PRODUCT-LEVEL MEASURES
Customer acceptance	How easy is it to automate the production process
Customer satisfaction level	Competitive reaction
Customer retention rate	Provides us with a sustainable competitive advantage
% of sales exported	Meets our cost goals
Purchase intent rate prior to market introduction	Cost of developing the product
Customer count, number of customers	Development efficiency
Taken off market	Measure of failure--First disappointment during the development
Length of product life	Ease of manufacture
Price/value as measured by the customer	Launched in budget
Relative sales level	Level of innovation achieved
Purchase repeat rate	Launched on time
Importance of the product to the retailer	Technical performance of product, performs to spec
Return rate from the field or customers	Relative product performance
Met revenue goals	Probability of success
Revenue growth	Development project progress vs milestones
Sales force acceptance	Met quality guidelines
Met minimum revenue level by year 5	Speed to market
Variance of sales from plan	Management's subjective assessment of success
Market position; Industry success rate	Ability to accrue political support within the firm
Met market share goals	Team satisfaction
Year 1 market share	Product received an award denoting technical excellence
Purchase trial rate	Technical success of the product
Product sales rate in test market	Impact on sales of other products; % cannibalization
Met sales volume goal	Product yield rate through the manufacturing process
MEASURES OF FINANCIAL PERFORMANCE	**PROGRAM MEASURES**
Break-even time after release	Program hit our 5-year new product objectives
Break-even time	Program exceeds our objectives
(from start of project)	Impact of the new product program on corporate performance
Attains margin goals	Return on investment for the new product development process
Attains profitability goals	Overall success of the product development program
Relative profits	New product program profitability
Return factor	New product program sales
Internal rate of return or return on investment	Subjective importance of our new product program

FIRM-BASED MEASURES
Can be line-extended--leads to future opportunities
Strategic fit with business
Hit a window of opportunity
Number of new products
% of products with high profits
% of profits under patent protection
% of profits provided by products less than 5 years old
% of sales provided by products less than 5 years old
% of sales under patent protection
PR value; amount of free advertising created by the product
Success/Failure rate of new products

Appendix 2 Study one: Exploratory study

Appendix 2.1 The questions asked in Survey I

About the company

***1. What is your industry sector?**

- ◯ Manufacturing
- ◯ Design
- ◯ Information Technology
- ◯ Financial
- ◯ Health Care
- ◯ Telecommunication services
- ◯ Energy

Other (Please specify)

***2. What is the size of the company (number of employees)?**

- ◯ Small (< 50)
- ◯ Medium (50-250)
- ◯ Large (> 250)

About you

3. What is your position in the organisation?

4. How many years have you worked for the organisation?

- ◯ < 1
- ◯ 1 - 2
- ◯ 2 - 4
- ◯ 4 - 5
- ◯ > 5

Motivation and current systems

5. What is the motivation for outsourcing/off shoring stages of Product Development e.g. outsourcing of the R&D, Design, Manufacturing stages?

6. What is the current system/ method used for measuring the success of Global Product Development?

Key Performance Indicators

7. What are the Key Financial Performance Indicators currently used for measuring the success of Global Product Development?

- [ ] Break-Even Time
- [ ] Profit Goals
- [ ] Return On Investment
- [ ] Margin Goals
- [ ] Other (Please specify)

8. What are the Key Customer Performance Indicators currently used for measuring the success of Global Product Development?

- [ ] Customer Satisfaction
- [ ] Market Share
- [ ] % Of Sales Exported
- [ ] Met Unit Vol. Goals
- [ ] Other (Please specify)

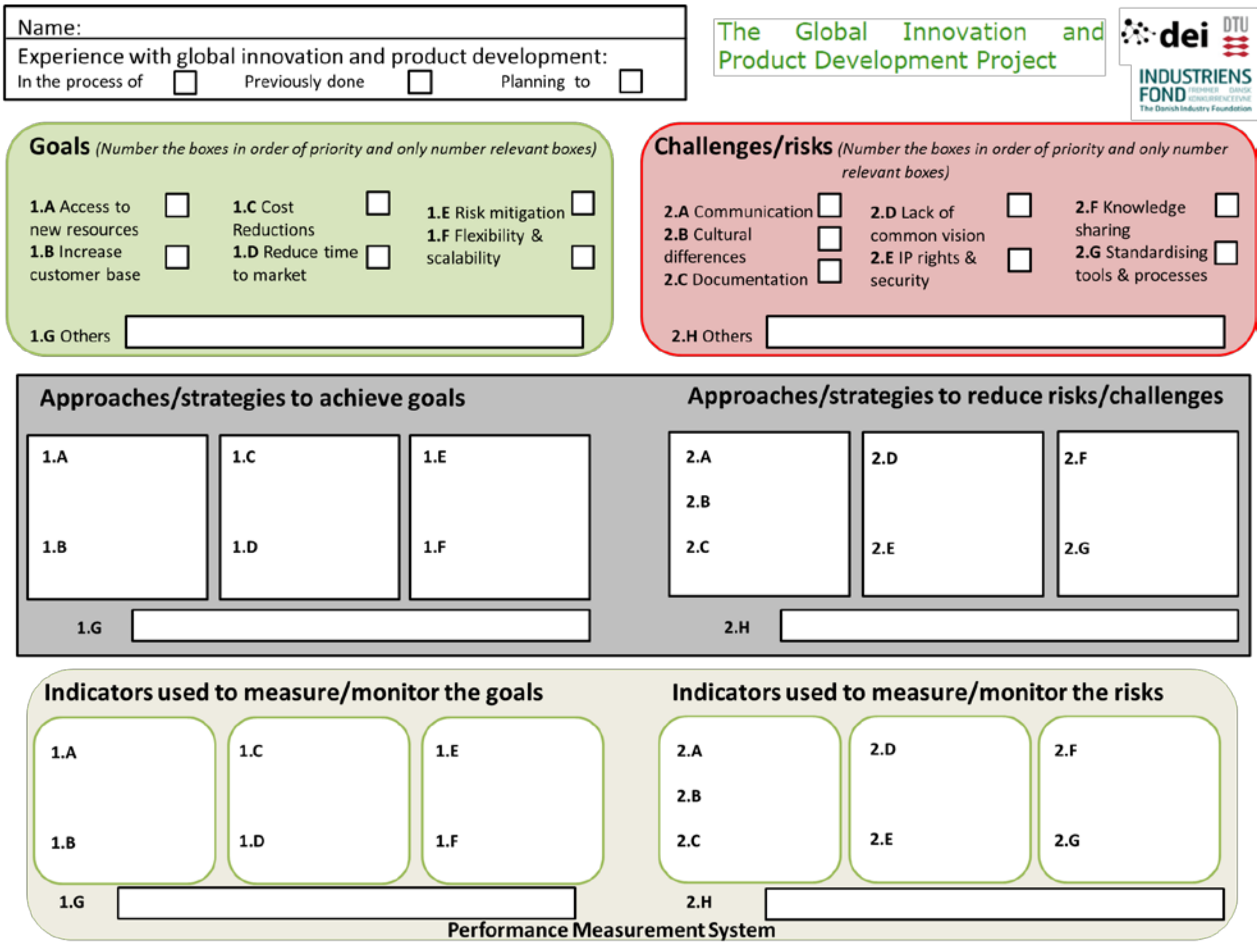
9. What are the Key Learning and Growth Performance Indicators currently used for measuring the success of Global Product Development?

- [ ] Sharing of Knowledge and Expertise
- [ ] Leads to Future Operations
- [ ] % New Product Sales
- [ ] Market Position
- [ ] Other (Please specify)

10. What are the Key Internal (company's processes and procedures) Performance Indicators currently used for measuring the success of Global Product Development?

- [ ] Development Cost
- [ ] Ease of Manufacture
- [ ] Speed to Market
- [ ] Project Vs Time plan
- [ ] Other (Please specify)

Appendix 2.2 The questions asked in survey II



Name:
Experience with global innovation and product development:
In the process of ☐ Previously done ☐ Planning to ☐

The Global Innovation and Product Development Project

dei DTU
INDUSTRIENS FOND

Goals *(Number the boxes in order of priority and only number relevant boxes)*

1.A Access to new resources ☐
1.B Increase customer base ☐
1.C Cost Reductions ☐
1.D Reduce time to market ☐
1.E Risk mitigation ☐
1.F Flexibility & scalability ☐
1.G Others

Challenges/risks *(Number the boxes in order of priority and only number relevant boxes)*

2.A Communication ☐
2.B Cultural differences ☐
2.C Documentation ☐
2.D Lack of common vision ☐
2.E IP rights & security ☐
2.F Knowledge sharing ☐
2.G Standardising tools & processes ☐
2.H Others

Approaches/strategies to achieve goals

1.A
1.B
1.C
1.D
1.E
1.F
1.G

Approaches/strategies to reduce risks/challenges

2.A
2.B
2.C
2.D
2.E
2.F
2.G
2.H

Indicators used to measure/monitor the goals

1.A
1.B
1.C
1.D
1.E
1.F
1.G

Indicators used to measure/monitor the risks

2.A
2.B
2.C
2.D
2.E
2.F
2.G
2.H

Performance Measurement System

Appendix 3 Study two: Multiple case studies

Appendix 3.1 Preparation for interviews at Company A and Company B

The interviews at Company A and Company B focussed on acquiring information in relation to the key areas illustrated below. The interview questions were divided into the modules below to allow the interviewer to switch between modules more easily based on the knowledge and experience of the interviewee.

Appendix 3.2 The interview questions at Company A and Company B

1. Experience with the collaboration and key motivations

- What is your experience working with the global R&D/ Danish R&D? What is your role?
- What was the reason for establishing the collaboration?
- What types of tasks are or will be sent to the global R&D? Why?
- What role does the global R&D play in the day to day activities at the company?
- Could you explain how the setup at the company has changed from how it used to be as a result of the collaborations?

2. Key challenges

- How has the collaboration with the global R&D affected the team in Denmark (and vice versa)? (Product development process: positive and negative).
- What do you consider to be the main issues/ critical areas with the collaborations?

3. Monitoring and measuring the critical factors

- How is the progress towards these critical factors monitored or measured?
- What are the key performance indicators used for measuring performance towards the critical factors? How are these selected?
- How do you know if a collaborative project has been successful?
- What kind of feedback is required to determine if a project has been successful/ unsuccessful?
- Are there high level measurements that impact the way expectations are communicated at a project-level?

4. Current processes

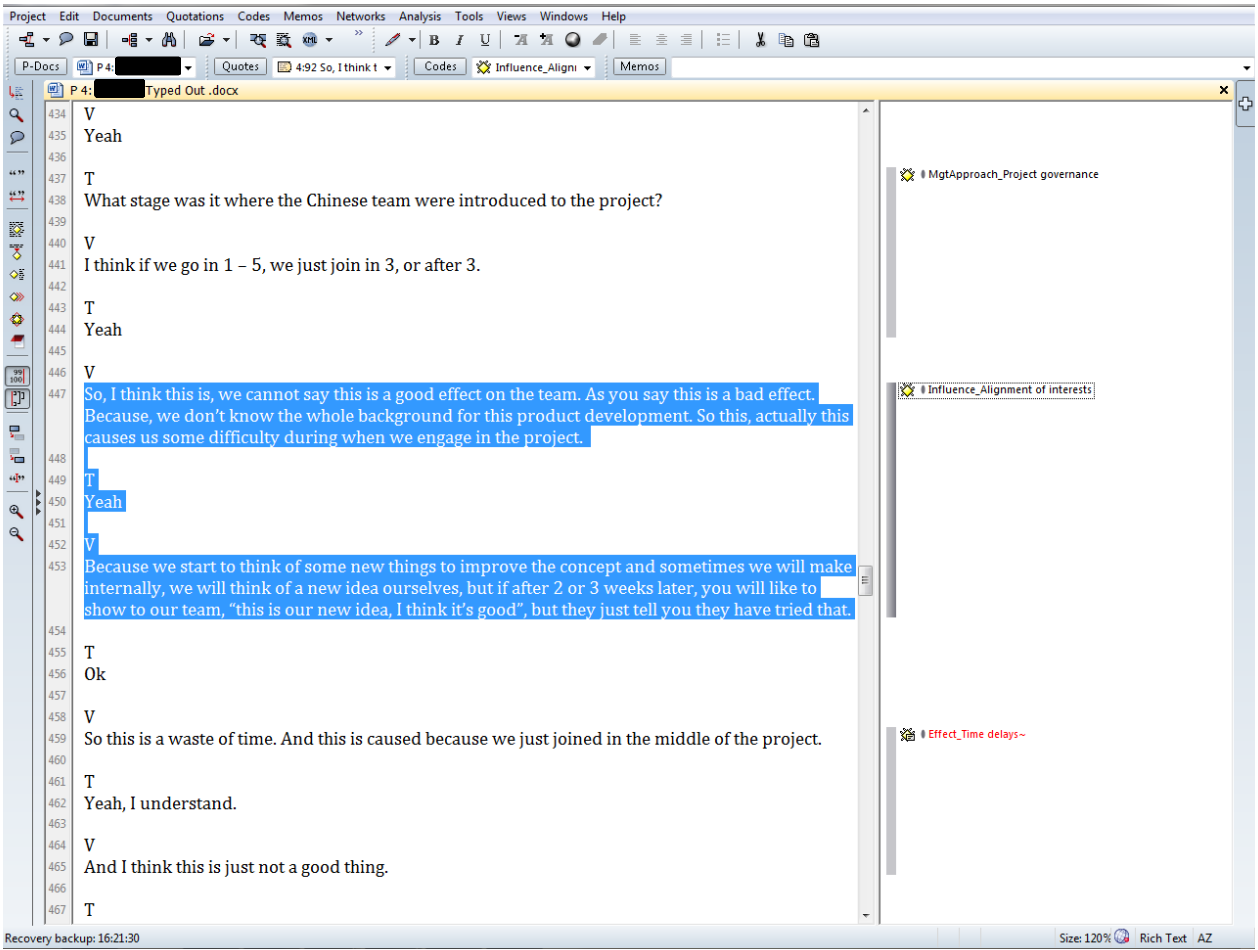
- What are the common tools and procedures used between the Danish and global R&D?
- What are the tools used for managing the collaboration?
- Are there difficulties with aligning procedures? Why?

Training (dependent on interviewee)

- What kind of training did the global R&D receive?
- What was the main goal of this training?
- What effects do you think the training has had on the global R&D?

Appendix 3.3 Example of coded transcript from interviews

An example of a section of transcript that has been coded is illustrated below. The transcripts were coded using the software program: Atlas.ti.



Appendix 3.4 The structure and categorisation of the detailed field notes

The detailed notes taken during the observations of the project meetings at Company A and Company B were summarised and inserted within the categories below to allow for further analysis. The scheme included codes based on the literature review and also those generated during the exploratory study and interviews during the multiple case studies. Additional codes were developed based on the observations to avoid the confinement of data. The researcher's reflections were also documented directly after the meeting for future reference. Examples of the categorised notes and reflections are presented below.

DATE	Stage of meeting in PD process	Challenge discussed	Influence at project-level	Strategy/ activity planned	Key performance indicator used	Type
17-02-2014	Concept development	Lack of common vision	Difficulties in managing Indian engineers' expectations	Review the deliverables in PD process	Number of deliverables met at milestone 1	Lagging

Researcher's reflections of meeting:

The purpose of the meeting was for the Indian engineers to present their results from the initial root cause analysis and for the Danish project manager to outline the next steps and deliverables for the project. The results were presented, however the Danish project manager raised concerns regarding the number of concepts proposed and the in-depth analysis conducted. It appears to be a reoccurring event that the Indian engineers are trying to maximise the improvement potential of the project and the Danish project manager is trying to keep the solution less ambitious. Based on his and others experience at the company, he thinks being too ambitious with changes can create problems.

DATE	Stage of meeting in PD process	Challenge discussed	Influence at project-level	Strategy/ activity planned	Key performance indicator used	Type
04-04-2014	Concept development	Documentation	Six sigma approach used by Indian engineers does not align with standard PD process at the company	Change wording in standard PD process to fit with six sigma approach	n/a	n/a

Researcher's reflections of meeting:

The purpose of the meeting was to review the status of the project in relation to the deliverables in the standard PD process at the company. The Danish project manager raised concerns regarding the six sigma process the Indian engineers are following, as this does not directly align with the deliverables in the standard PD process. The Indian engineers disagreed with this and insisted on using the process they had recently received training in. The majority of the meeting was spent re-aligning the tasks in the six sigma process with the tasks in the standard PD process, which was time consuming.

Appendix 4 The method of support

Appendix 4.1 Agenda for the implementation of the KPI selection toolkit

Agenda

The KPI Toolkit - a structured approach for selecting project-level Key Performance Indicators.

09:00 - 09:20 **Introduction**

Evaluation forms (before)
An overview of the KPI Toolkit
Process flow

09:20 - 09:50 **Package 1**
Key concepts of Performance Measurement

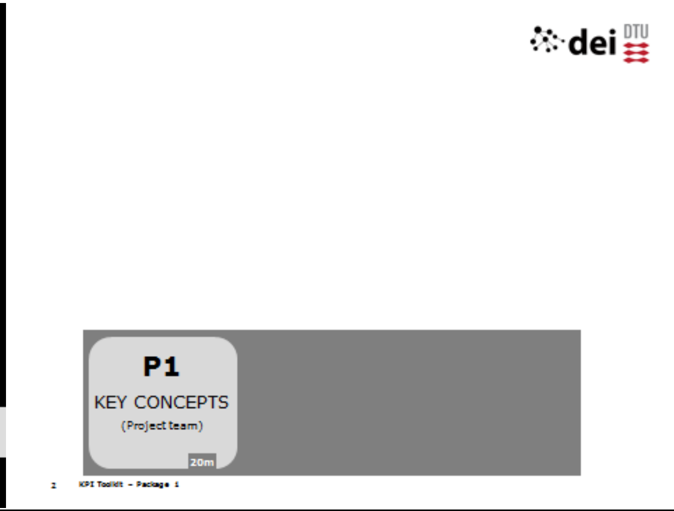
09:50 - 11:50 **Package 2**
Identification of critical factors
Selection of KPIs
KPIs to PD plan

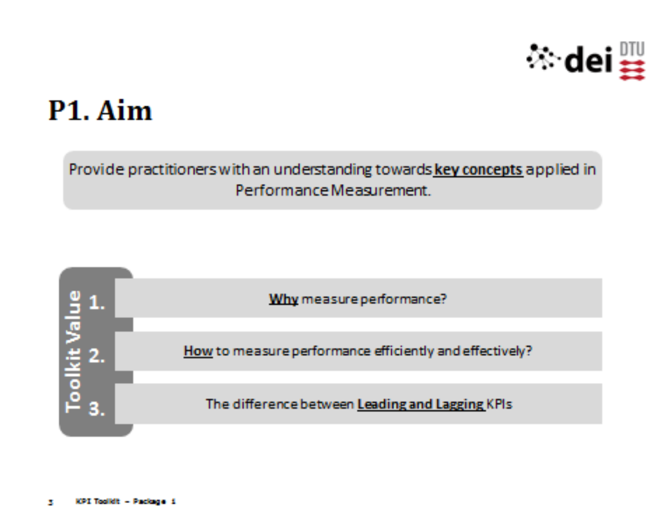
11:50 - 12:20 **Package 3**
Reporting the KPIs

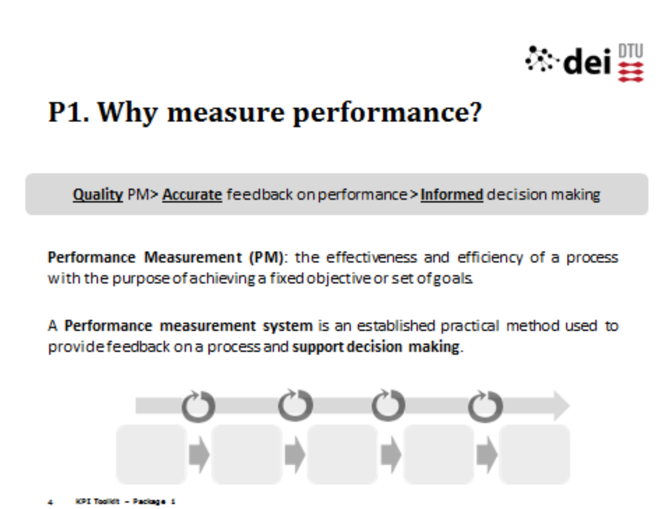
12:20 - 12:30 **Wrap-up**
Evaluation forms (after)

Appendix 4.2 The KPI selection toolkit

Phase 1: Clarify key concepts







P1. Why measure performance?

How can we improve if we do not know how we are performing?

To improve the way we deliver the workshops, there is a requirement for performance related information from our customers (You!), which we obtain and evaluate using feedback forms.

Important to select measures which are alligned with **previously outlined objectives**... You get what you measure!

5 KPI Toolkit – Package 1

P1. How to measure performance?

The key to successful performance measurement:

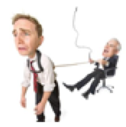
1. Identify the **critical factors impacting project success.**
2. Select Key Performance Indicators (KPIs) that monitor the factors.
3. Allign and implement the KPIs with current processes.

Key Performance Indicators (KPIs): quantifiable metrics that help an organisation measure the success of critical factors.

Use KPIs to make process improvements rather than monitoring individual behaviour:

Individual KPI: *Time to complete task.*

Process KPI: *Number of planned iterations.*



6 KPI Toolkit – Package 1

P1. Difference between Leading and Lagging

"Our focus is not on KPIs that measure an ***outcome*** *e.g. missed deadlines, rather we want to focus on setting up KPIs which* ***prevent*** *us from missing deadlines, and hence,* ***drive*** *performance"*

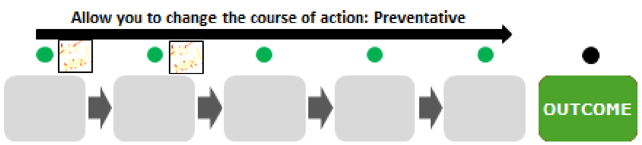
[redacted]

Leading KPIs– measure activities that impact future performance and are drivers of performance.

Lagging KPIs– measure the output of past activity and typically consist of financial indicators.

7 KPI Toolkit – Package 1

P1. Difference between Leading and Lagging



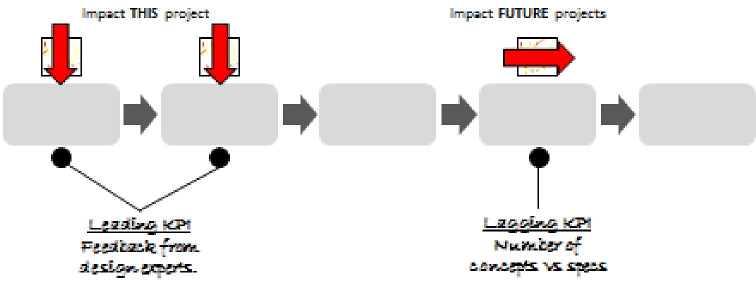
● **Lagging KPIs**– measure the output of past activity and typically consist of financial indicators.

● **Leading KPIs**– measure activities that impact future performance and are drivers of performance.

8 KPI Toolkit – Package 1

P1. Leading and Lagging example

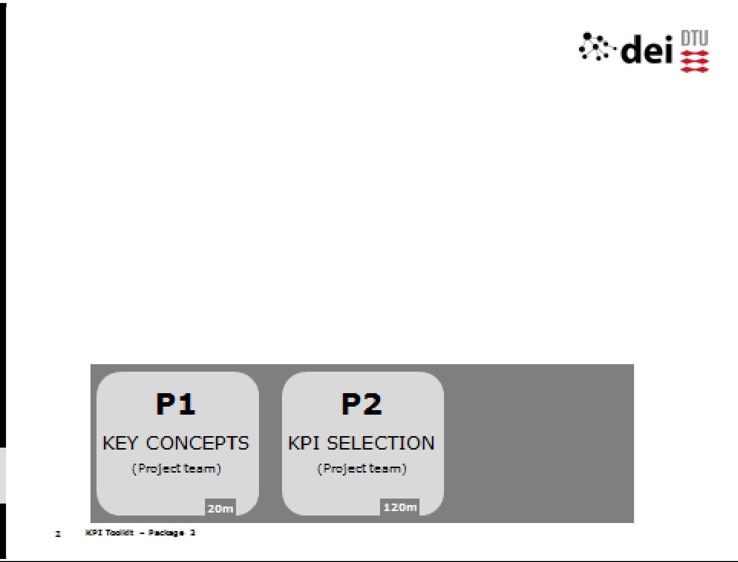
A lack of common vision between two teams led to time delays later in the project.

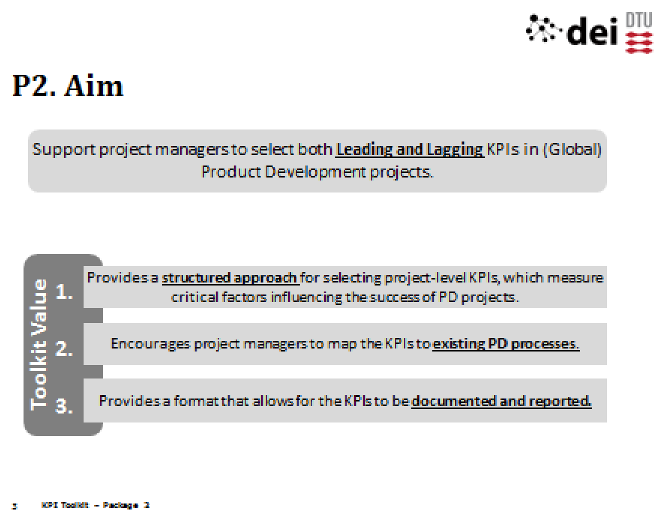


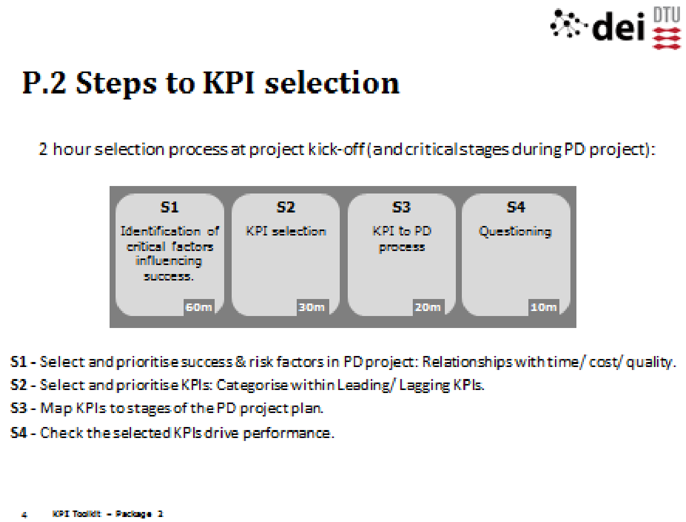
Link to more examples (Coming soon): www.GIPD/KPItoolkit/LeadLag.dk

9 KPI Toolkit – Package 1

Phase 2: KPI selection




dei DTU
P2. Aim
Support project managers to select both Leading and Lagging KPIs in (Global) Product Development projects.
Toolkit Value
1. Provides a structured approach for selecting project-level KPIs, which measure critical factors influencing the success of PD projects.
2. Encourages project managers to map the KPIs to existing PD processes.
3. Provides a format that allows for the KPIs to be documented and reported.
3 KPI Toolkit – Package 2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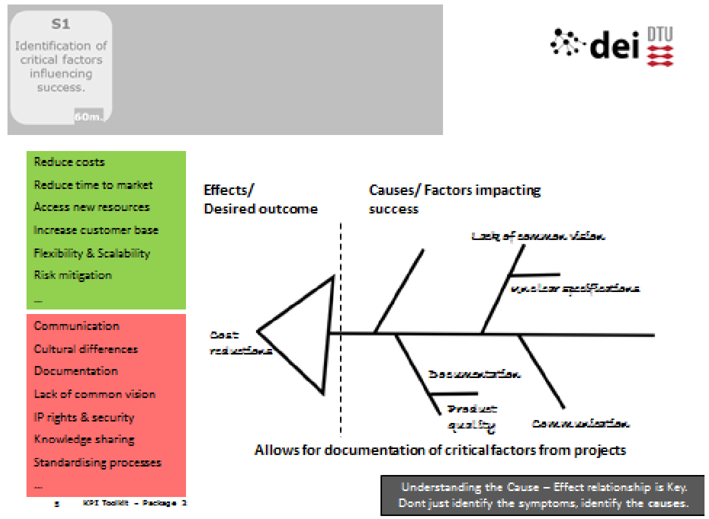
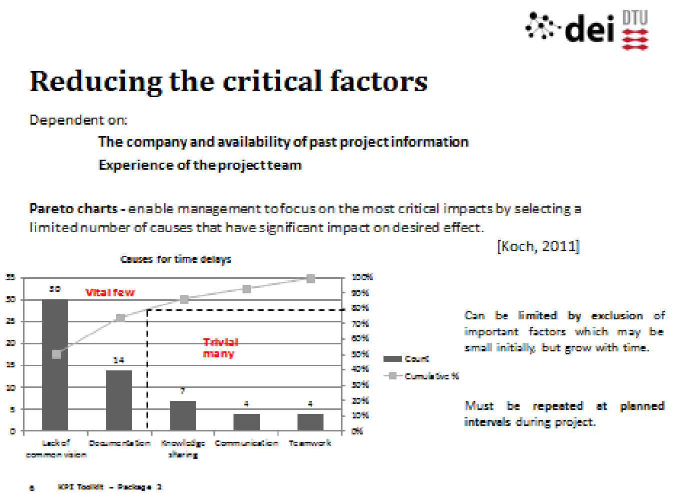
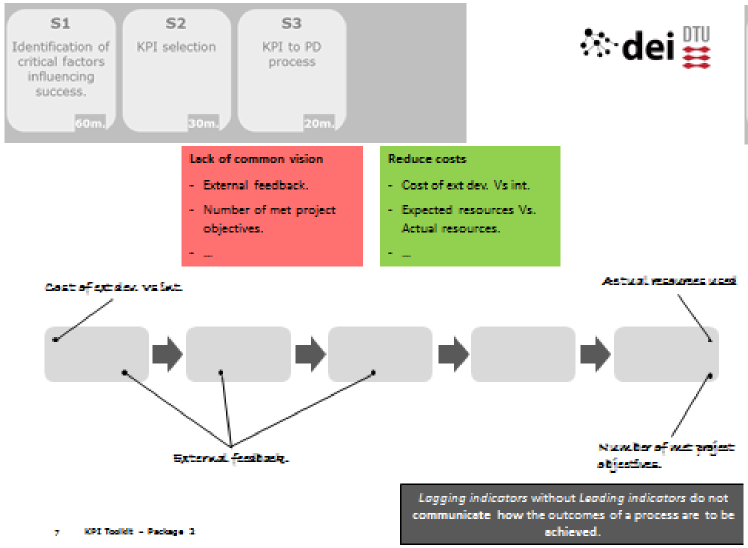
P.2 Steps to KPI selection
2 hour selection process at project kick-off (and critical stages during PD project):
S1 Identification of critical factors influencing success. 60m
S2 KPI selection 30m
S3 KPI to PD process 20m
S4 Questioning 10m
S1 - Select and prioritise success & risk factors in PD project: Relationships with time/ cost/ quality.
S2 - Select and prioritise KPIs: Categorise within Leading/ Lagging KPIs.
S3 - Map KPIs to stages of the PD project plan.
S4 - Check the selected KPIs drive performance.
4 KPI Toolkit – Package 2


S1 Identification of critical factors influencing success. 60m
dei DTU
Reduce costs
Reduce time to market
Access new resources
Increase customer base
Flexibility & Scalability
Risk mitigation
...
Communication
Cultural differences
Documentation
Lack of common vision
IP rights & security
Knowledge sharing
Standardising processes
...
Effects/ Desired outcome
Causes/ Factors impacting success
Lack of common vision
Unclear specifications
Cost reductions
Documentation
Product quality
Communication
Allows for documentation of critical factors from projects
Understanding the Cause – Effect relationship is Key. Dont just identify the symptoms, identify the causes.
5 KPI Toolkit – Package 2


dei DTU
Reducing the critical factors
Dependent on:
The company and availability of past project information
Experience of the project team
Pareto charts - enable management to focus on the most critical impacts by selecting a limited number of causes that have significant impact on desired effect.
[Koch, 2011]
Causes for time delays
Vital few
Trivial many
30
14
7
4
4
Lack of common vision
Documentation
Knowledge sharing
Communication
Teamwork
Count
Cumulative %
Can be limited by exclusion of important factors which may be small initially, but grow with time.
Must be repeated at planned intervals during project.
6 KPI Toolkit – Package 2


S1
Identification of critical factors influencing success.
60m.
S2
KPI selection
30m.
S3
KPI to PD process
20m.
dei DTU
Lack of common vision
- External feedback.
- Number of met project objectives.
- ...
Reduce costs
- Cost of ext dev. Vs int.
- Expected resources Vs. Actual resources.
- ...
Cost of ext dev. vs int.
Actual resources used
External feedback.
Number of met project objectives.
Lagging indicators without Leading indicators do not communicate how the outcomes of a process are to be achieved.
7 KPI Toolkit – Package 3


S1
Identification of critical factors influencing success.
60m.
S2
KPI selection
30m.
S3
KPI to PD process
20m.
S4
Questioning
10m.
dei DTU
CHECK LIST
- Are the KPIs alligned with business unit KPIs?
- Are the KPIs sustainable with time?
- Do the KPIs provide accurate and timely feedback toward the most critical influences on project success?
- Is the relationship between Leading and Lagging KPIs understood?
- ...
Ensure the KPIs allow for continuous improvement towards project performance.
8 KPI Toolkit – Package 3

Phase 3: Monitor and measure

KPI Toolkit

Package 3

P1	P2	P3
KEY CONCEPTS (Project team) 20m	KPI SELECTION (Project team) 120m	REPORTING (Project Mgt.) 20m

2 KPI Toolkit – Package 3

P3. Aim

Provide practitioners with the templates required in order to sufficiently **document and report** the selected KPIs.

Toolkit Value

1. The KPI template encourages the consideration of KPI **applicability and implementation.**
2. Allignment of KPIs with **company infrastructure.**
3. The review of KPIs ensures the KPIs do not remain static and **adapt to the environment** they are to be implemented.

3 KPI Toolkit – Package 3

P3. KPI Template

Implementation

Measure	[illegible]
KPI	[illegible]
Purpose	[illegible]
Formula	[illegible]
Responsibility	[illegible]
Target	[illegible]
Min.	[illegible]
Max.	[illegible]
Frequency of measurement	[illegible]
Stage during PD	[illegible]
KPI categorisation	[illegible]
Lagging KPI related to	[illegible]
Notes	[illegible]

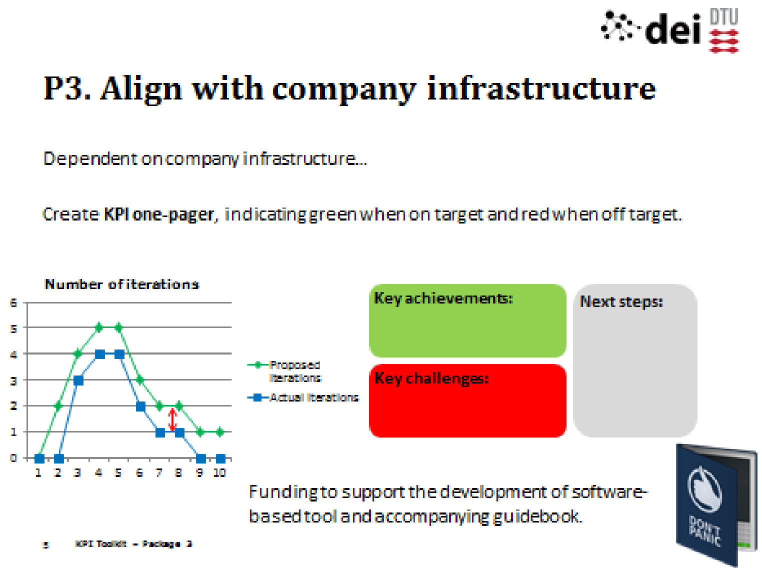
Target per month for each KPI to ensure the process is on going and not static.

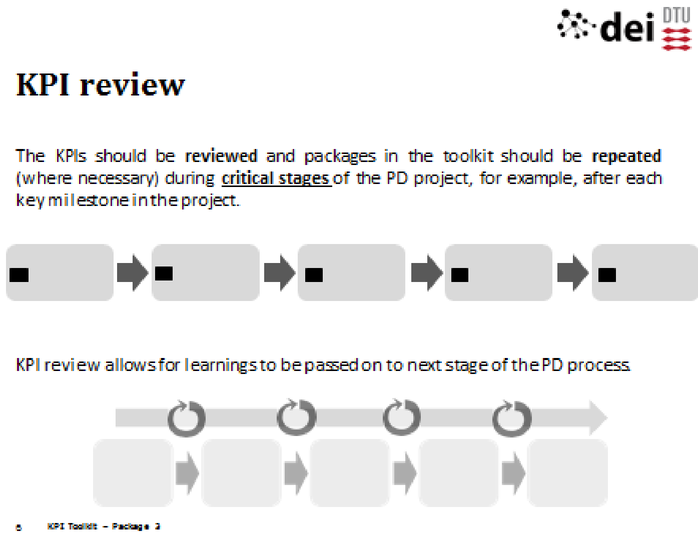
Define action if off target.

Complete template for each KPI.

Many of the factors in the KPI template will have been discussed during P2.

4 KPI Toolkit – Package 3


dei DTU
P3. Align with company infrastructure
Dependent on company infrastructure…
Create **KPI one-pager**, indicating green when on target and red when off target.
Number of iterations
Proposed iterations
Actual iterations
Key achievements:
Key challenges:
Next steps:
Funding to support the development of software-based tool and accompanying guidebook.
5 KPI Toolkit – Package 3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KPI review
The KPIs should be **reviewed** and packages in the toolkit should be **repeated** (where necessary) during critical stages of the PD project, for example, after each key milestone in the project.
KPI review allows for learnings to be passed on to next stage of the PD process.
6 KPI Toolkit – Package 3

Appendix 4.3 Survey for evaluation of the KPI selection toolkit

<u>Before the workshop</u>

dei DTU

INDUSTRIENS FOND FREMMER DANSK KONKURRENCEEVNE The Danish Industry Foundation

Evaluation of the KPI Toolkit

All feedback forms will be kept anonymous.

Pre Evaluation

Please rate the following statements:

- The critical steps required for selecting KPIs are understood.

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
○	○	○	○	○

- The difference between Leading and Lagging KPIs is understood.

Strongly agree	Agree	Neutral	Disagree	Strongly disagree
○	○	○	○	○

Please state the KPIs selected for the project.

After the workshop

Evaluation of the KPI Toolkit

All feedback forms will be kept anonymous.

Post Evaluation

- What was your overall impression of the KPI Toolkit in terms of:

	Extremely	Very	Somewhat	Slightly	Not at all
A) Usefulness					
B) Applicability					

Please rate the following statements:

- The critical steps required for selecting KPIs are understood.

  Strongly agree — Agree — Neutral — Disagree — Strongly disagree

- The difference between Leading and Lagging KPIs is understood.

  Strongly agree — Agree — Neutral — Disagree — Strongly disagree

- Please state the KPIs selected for the project.

The KPI Toolkit:

- Provided a structured approach for selecting project level KPIs.

  Strongly agree — Agree — Neutral — Disagree — Strongly disagree

- Supported the selection of both Leading and Lagging KPIs.

  Strongly agree — Agree — Neutral — Disagree — Strongly disagree

- Is there anything missing from the KPI Toolkit that is required to set up KPIs?

KPI Toolkit - Post Evaluation

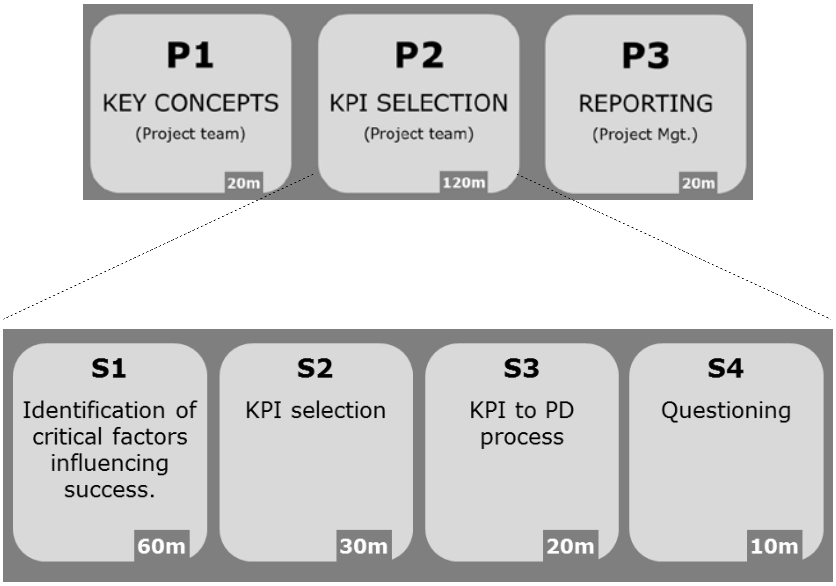
Appendix 4.4 Interview questions for evaluation of the KPI selection toolkit

The interview should last no more than **<u>10-15 minutes</u>** and will focus on the experiences of The KPI Toolkit, which was tested at [redacted] in 2015.

INTRODUCTION:

The specific aim of the interview is to **<u>understand the impact that the KPI selection toolkit had at the company</u>**, in relation to your everyday tasks.

I would just like to refresh your memory of the different activities conducted during the workshop.



MAIN BODY:

As a result of the workshop, information regarding the critical impact factors for the project and the KPIs to monitor these was documented.

- How has this information been used?
- If it hasn't, how will it be used in the future?

Furthermore, there were a number of actions set up in the team, including **creating a document to align the interests of different departments during the project**.

- Have any of these actions been implemented?
- If not, why? Are there plans to implement them?

How has the KPI Toolkit impacted your behaviour towards this project and other projects?

Have you put any of the learning from The KPI Toolkit to use?

Are you able to teach the new skills/attitudes to others?

Finally, Could you describe your overall experience in regards to the using The KPI Toolkit?

WRAP UP:

Do you have any further questions regarding The KPI Toolkit?

- Would it be possible to set up interviews with the other employees who participated during the workshop?

Appendix 5 Papers

Paper 1	Performance Measurement in Global Product Development
Reference	*Taylor, T. P., Ahmed-Kristensen, S. 2013. "Performance Measurement in Global Product Development." Proceedings of the 19th International Conference on Engineering Design – ICED, 2013, Seoul, South Korea.*
Paper 2	The applicability and coherence of key performance indicators in global product development
Reference	*Taylor, T. P., Ahmed-Kristensen, S. 2014. "The applicability and coherence of key performance indicators in global product development." Proceedings of the 13th International Design Conference – DESIGN, 2014, Dubrovnik, Croatia.*
Paper 3	Key performance indicators: Global product development
Reference	*Taylor, T. P., Ahmed-Kristensen, S. 2014. "Key performance indicators: Global product development." Proceedings of the 21st EurOMA conference: Operations management in an innovation economy, 2014, Palermo, Italy.*
Paper 4	Global product development projects: Measuring performance and monitoring the risks
Status	*Submitted to the journal of Production Planning & Control.*
Paper 5	Longitudinal observations of globally distributed design teams: The impacts on Product Development
Reference	*Taylor, T. P., Ahmed-Kristensen, S. 2015. "Longitudinal observations of globally distributed design teams: The impacts on Product Development." Proceedings of the 20th International Conference on Engineering Design, 2015, Milan, Italy.*
Paper 6	Globally distributed design teams: The impacts on product development
Status	*Submitted to the International Journal of Operations & Production Management.*
Paper 7	Global product development: KPI selection support
Reference	*Taylor, T. P. and Ahmed-Kristensen, S. (2016), "Global product development: KPI selection support" 14th International Design Conference – DESIGN, 2016, Dubrovnik, Croatia.*

Appendix 5.1 Paper I

Reference: Taylor, T. P., Ahmed-Kristensen, S. 2013. "Performance Measurement in Global Product Development." *Proceedings of the 19th International Conference on Engineering Design – ICED*, 2013, Seoul, South Korea.

Authors	Taylor, T. P., Ahmed-Kristensen, S.
Title	Performance Measurement in GPD
Published in	Proceedings of the 19th International Conference on Engineering Design, ICED 2013, Seoul, South Korea.
Research aim	To evaluate the success of GPD, there is a requirement for performance measurement. There exists a need to understand current performance measurement frameworks, their applicability within the context of GPD and KPIs used in GPD projects in industry.
Research stage	Design Research Methodology: Research clarification → Descriptive study I.
Research approach	A survey conducted with 28 companies to collect information on key challenges and motivations for GPD and KPIs used.
Summary of findings	The analysis of literature highlighted the lack of applicability of current performance measurement frameworks when considering key success and challenge factors in GPD. The empirical studies highlighted the importance of cultural differences and communication as key challenges in GPD and the opportunity to reduce costs as a key motivation, with these findings confirmed in literature. KPIs used in GPD projects were identified with the majority related to traditional KPIs typically found in conventional PD: development cost, development time and customer satisfaction. "Other" KPIs, than those traditionally found in conventional PD, included Capability of supplier delivery and Number of sales from new location, which could not be directly aligned with performance measurement frameworks in literature.
Contribution	The paper contributes to the thesis by highlighting the lack of cohesion between current performance measurement frameworks in literature with key motivations, challenges and KPIs in GPD projects and hence, indicates the requirement for additional performance dimensions than those proposed in current frameworks, such as the Balanced Scorecard.

ICED13
INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED13
19-22 AUGUST 2013, SUNGKYUNKWAN UNIVERSITY, SEOUL, KOREA

PERFORMANCE MEASUREMENT IN GLOBAL PRODUCT DEVELOPMENT

Thomas Paul TAYLOR, Saeema Ahmed KRISTENSEN
Technical University of Denmark, Denmark

ABSTRACT

An organisation looking to form collaborations across borders is a consequence of an increasingly competitive world market. Recent studies highlighted key challenges and success factors organisation's face when globalising stages of product development. To optimize performance along these factors there is a requirement for the process to be monitored and measured relative to the business strategy of an organisation. It was found that performance measurement is a process that helps achieve sustainable business success, encouraging a learning culture within organisations. To this day, much of the research into how performance is measured has focussed on the process of product development. However, exploration of performance measurement related to global product development is relatively unexplored and a need for further research is evident.

This paper contributes towards understanding how performance is measured in global product development. More specifically, results from a survey and interviews highlight a need for further development in current performance measurement frameworks used in product development to facilitate the key factors and metrics in global product development.

Keywords: outsourcing, key performance indicators, design management, organisation of product development, decision making

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1 INTRODUCTION

The potential of reducing costs by offshoring and outsourcing parts of product development (PD) has led to global product development (GPD) becoming increasingly popular among engineering companies, especially within Europe. Advancements in communication technology have lowered the barriers of entry for organisations wishing to collaborate across borders. However, with the relocation of stages of the development process such as production and research and development, the level of uncertainty increases in the process and organisations face challenges related to culture, communication and organisational change management. For an organisation to achieve sustainable business success in the demanding and competitive world marketplace, a company must integrate relevant performance measures [Neely *et al.*, 2000]. There is therefore a need to closely monitor the process, providing indications of how well an organisation is performing towards the goals outlined at the outset. This paper aims to contribute to the further understanding of performance measurement in GPD. The motivations and challenges related to the relocation of stages of the PD process and the performance measures used to assess the success of a GPD project are explored in the paper. Recommendations towards a performance measurement system for GPD are presented.

2 LITERATURE REVIEW

2.1 Global Product Development

GPD is the globalisation of tasks and activities throughout the PD process, from the start of the process of the fuzzy front-end and R&D to manufacturing and maintenance activities [Hansen and Ahmed-Kristensen, 2012]. The globalisation of tasks may involve outsourced engineering work along with captive offshore engineering facilities. The processes of outsourcing and offshoring are defined as follows: Outsourcing; a different company owns the foreign organisational unit where the relocated work is completed and Offshoring; the company in question owns the foreign organisational unit where the relocated work is completed. An increasing demand for organisations looking to reduce development costs, increase access to new competencies and improve development quality whilst shortening their time to market has led to organisations looking to outsource or offshore stages of their development process. According to a study by the Aberdeen Group [2005], 78% of 125 enterprises across multiple manufacturing industries pursue Global Design as a strategy for reducing the cost of design. Globalising PD has an impact not only on the product and process, but also on the organisation as a whole and introduces new challenges. A change in PD activities and processes ultimately leads to organisational change management. Managing change across globally dispersed teams is a challenging task [Aberdeen group, 2005]. Hansen and Ahmed-Kristensen [2012] identified nine key challenges related to GPD and argued that cultural differences within different organisations influence ‘the way people do things’, with communication and knowledge sharing acting as a barrier of entry for globally collaborating organisations. A further challenge which is common throughout the literature is the lack of a global strategy and creating a common vision amongst globally dispersed teams. Eppinger and Chitkara [2006] suggest ten key success factors for GPD including collaborative culture, organisation change management and management priority. The ten factors are interlinked and their significance contextually dependent. To tackle the challenges in GPD and monitor their success rate, the global decision making framework (GDM) is suggested by Hansen and Ahmed-Kristensen [2012] as a guideline for companies. For the framework to be successful, the requirement for constant feedback to the management on the performance of the process is needed. This highlights the need for a defined set of Key Performance Indicators (KPIs) during the evaluation stage of the GDM framework.

2.2 Performance measurement

Performance measurement can be defined as a search for optimizing the relationship between the input and output of a system, with the purpose of achieving a fixed objective and is measurable with the quantification of the effectiveness and/or the efficiency of an action or activity [Poulet *et al.,* 2010]. The approach to performance measurement during the creation of the “Tableau de Bord” performance measurement framework [Epstein and Manzoni, 1998] relies heavily on the mission and vision of a project for an accurate performance measurement to be made (see Figure 1). Before establishing the KPIs, a clear mission and vision must be transformed into a set of objectives. These objectives differ depending on the context of implementation, i.e. the unit or sector of the organisation in which they are to be implemented or the goal or outcome required of a particular project. The unit then translates these objectives into Key Success Factors (KSFs), which are transformed into a series of KPIs to allow for performance measurement relative to the mission and vision at the outset.

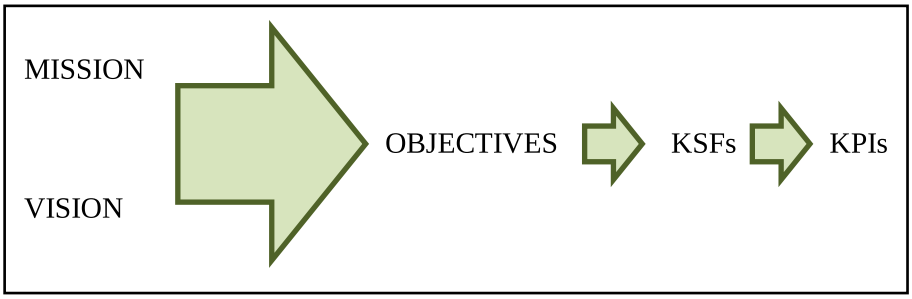

Figure 1 Epstein and Manzoni's [1998] approach to performance measurement.

Over the past few decades, research in performance measurement has predominantly been confined to PD rather than GPD. Currently, many organisations base their decision on how well a PD project performed solely on financial indicators [Kitinaka *et al.*, 2012]. When considering GPD, measuring performance from only financial indicators does not provide the means for accurate feedback. If a GPD project is deemed a failure financially in the short term, the long-term rewards of diving into new globally dispersed markets could act as a positive with regard to future collaborations, globalisation of knowledge and expertise and business dealings. When globalising PD, tackling performance measurement at an operational level can be extremely multifaceted and subjective, often depending on the type of organisation, project or individual involved [Masri *et al.*, 2010]. There is a lack of research focusing on what KPIs are required in order to successfully measure performance during GPD. A study conducted by Griffin and Page [1996] looked at the KPIs companies use for measuring performance in PD. 46 different indicators were identified from a total of 77 different articles and a company survey with 50 responses produced 34 different indicators that companies currently use [Griffin and Page 1996]. Some of the most popular indicators included customer satisfaction, profit goals, market position and development cost. A further study uncovered 66 variable KPIs along 20 different performance related dimensions [Cooper, 1998]. However, many of the KPIs found in Cooper's study were similar in nature, and grouping along different performance dimensions such as customer-based success, financial success and technical performance success was possible.

2.3 Framing the performance measures

The categorisation of KPIs across broader performance dimensions is a consistent practise among researchers when creating a framework for performance measurement. The creators of the Balanced Scorecard [Kaplan and Norton, 1996] suggest two basic types of KPI in any organisation; leading and lagging. Leading indicators are considered to be performance drivers (Revenue growth and mix, Customer satisfaction, Quality assurance, etc. displayed in Table 1) and lagging to be outcome measures (Financial, Customer, Internal and Learning and growth displayed in Table 1). The leading indicators tend to be more variable in nature, whereas the lagging or outcome indicators are more fixed. The lagging indicators or performance dimensions act as the foundation for the selection of the more focussed KPIs or leading indicators. The dimensions selected rely heavily on the business strategy and culture within the organisation. The development of such a framework allows for a generalisation and categorisation of performance measures for a specific project.

Table 1 Kaplan and Norton's [1996] performance measurement framework for the Balanced Scorecard

Financial *(How do we look to our shareholders?)*	**Customer** *(How do customers see us?)*	**Internal** *(What must we excel at?)*	**Learning and Growth** *(Can we continue to improve and create value?)*
- Revenue growth and mix - Cost reduction - …	- Customer satisfaction - Market share - …	- Quality assurance - Development time - …	- Sharing of knowledge and expertise - Individual and organisational allignment - …

Many of the KPIs uncovered during the studies by Griffin and Page [1996] and Cooper [1998] can be placed within the framework suggested by Kaplan and Norton [1996]. However, the KPIs uncovered during the two studies were PD specific rather than GPD specific. The motivations and challenges related to GPD add further complexity to the KPIs to be used in performance measurement.

3. METHODOLOGY

Before undertaking empirical research the motivations and challenge factors described in literature for GPD contrasted with the current performance measurement framework presented by Kaplan and Norton [1996]. Highlighted by Epstein and Mazoni [1998], incorporating business strategy into a performance measurement system is paramount to its successful employment and the requirement to understand the relationship between the motivations and challenge factors for GPD and current measurement systems is evident. Hence the challenges and success factors were categorised amongst the performance dimensions suggested by Kaplan and Norton [1996].The categorisation process (Table 2 and Table 3) was a preliminary analysis of the relationship between the success and challenge factors for GPD [Hansen and Ahmed-Kristensen, 2012 and Eppinger and Chitkara, 2006] with the performance dimensions outlined by Kaplan and Norton [1996]. The aim of this exercise was to investigate whether there was a need for further developments in the performance measurement framework presented to incorporate the success and challenge factors outlined for GPD. Given the high subjectivity associated with performance measurement and the success and challenge factors, concrete conclusions were not made based solely on this exercise and any grouping or relationships were also based on the authors' knowledge and experience with the subject. Table 2 presents the factors that could potentially fit within the performance measurement framework. Table 3 presents those which do not fit and could create new performance dimensions. The factors marked with (*) hold a link to multiple performance dimensions. Communication for example could potentially fit under all of the dimensions and therefore has been put in a group in Table 3. It is interesting to see a minimal amount of factors under the financial and customer dimensions. The majority of the success factors can be linked to different performance dimensions, in contrast to the challenge factors. This is largely due to the nature of the challenge factors. The success factors are more goal orientated, similar to the performance dimensions, however the challenges are more risk related. Also, the framework proposed is not specifically designed for GPD.

Table 2 Categorisation of success and challenge factors for GPD under performance measurement framework.

Performance dimensions for PD					
Customer	**Financial**	**Internal processes**	**Learning and growth**		**Key:**
Product Modularity		Organisation change management Infrastructure Data Quality Process Modularity* Core Competence (Organisational structures)	Collaborative culture* (Knowledge sharing)		* - Factor fits under multiple headings (Challenge factors) Success factors

Table 3 Success and challenge factors for GPD unable to fit within performance measurement framework.

Performance dimensions for GPD		
Unknown entity	**Unknown entity**	**Unknown entity**
(Communication*)	(Synchronising distributed designs)	Governance and Project Management
(Cultural differences)	(Standardizing tools and processes*)	Management priority

(Documentation*) (IP rights and IP security)		(Lack of a common vision)

According to Manzoni and Epstein [1998], understanding the relationship between the goals and the performance measures is key in the design of a performance measurement system. The exercise highlighted a gap between the motivations and challenges for GPD and the current performance measurement systems for PD. The challenge and success factors require transforming into KPIs to allow for distribution within the framework. Furthermore, the grouping of the factors in Table 3 suggests there is a need for further performance dimensions or lagging indicators if the framework is to accommodate the factors for GPD. Drawing on these conclusions, there was a need to take a closer look at the challenge and success factors and the performance measurement methods related to GPD rather than PD. The relationship between the KPIs for GPD and the performance measurement system outlined by Kaplan and Norton [1996] could then be addressed.

3.1 Research Aim

The aim of the research was to investigate the methods of measuring performance of a project when parts of PD are outsourced or offshored. This was twofold: firstly the literature review mapped the success and challenge factors related to GPD against established performance measurement frameworks. Secondly the empirical studies in the following section set out to identify the KPIs used in practice as a method of measuring performance in GPD.

3.2 Research approach

The objective for the empirical research was to gain an insight into the organisation’s current method of measuring performance and how this compared with the framework for performance measurement set out in literature. Two empirical studies were conducted: a survey and interviews. The survey focused primarily on understanding the motivations and current performance measurement systems in GPD and was the primary data source. The interviews were semi structured and contributed towards a broader understanding of the challenges involved with performance measurement in GPD and how these are overcome in practice. The results from the interviews were used as a secondary data source. A coding scheme for the data analysis for each of the studies was developed. This was an iterative process and new categories were developed in the coding scheme as more data was acquired in order to avoid the confinement of data. The knowledge gained for each of the studies influenced the direction of the study that followed and also the data coding scheme. The approach allowed for a process of on-going data reflection with developments to the data collection framework made where necessary. This approach was employed due to the high subjectivity of performance measurement.

3.3 Participants

The participants were divided into two groups, the participants for the survey and the participants for the interviews. The total number of surveys dispatched was one hundred, which was based on other similar studies regarding performance measurement in the literature [Cooper, 1998 and Griffin and Page, 1996]. Thirty-eight of the surveys were distributed to organisations that had previously attended a workshop held at Denmark’s Technical University regarding GPD and currently outsourced or offshored stages of their PD. The remaining sixty-two were passed to a sourcing community for further distribution. From one hundred surveys, there were a total of twenty-eight usable responses (see Table 4 for overview of participants). Twenty-seven of the respondents had their headquarters based in Denmark and one respondent in the United Kingdom. When responding to the survey, a number of participants indicated that they would be interested in a follow-up interview. Six of these participants were selected for an interview with each from an organisation with the headquarters in Denmark. Table 5 shows the breakdown of the participants for the interviews and exercises.

Table 4 Twenty-eight survey respondents

	Criteria	Number of organisations
Company size:	Small (<50)	7
	Medium (50-250)	2
	Large (>250)	19
Industry sector:	Manufacturing	17
	Information Technology	9
	Energy	1
	Other	1
Job Title:	Engineer	4
	Senior Consultant	4
	Sourcing Manager/ Director	6
	Project Manager	3
	Founder	1
	Managing Director	2
	Senior Manager	5
	Scientist	1
Number of years at organisation:	<1	2
	1 to 2	4
	2 to 4	3
	4 to 5	2
	>5	14

Table 5 Six interviewees

Industry type	Years at organisation (Years)	Job title
Consultancy	12	Founder
Manufacturing	8	Project Manager
Manufacturing	5	Senior Consultant
Consultant	4	Senior Consultant
Manufacturing	>30	Engineer
Consultancy	1.5	Managing Director

3.4 Data collection

A quantitative approach to data collection was adopted for the survey results. The survey was kept short (between six and ten minutes to complete) to maximise the response potential. SurveyMonkey™ was used as a platform for developing the online survey. Multiple choice questions were designed where possible to help with the gathering and analysis of the data. After the open ended questions, a number of leading questions, when considering the KPIs that are used for GPD, were developed to ensure the respondent considered answering along the four performance dimensions outlined in the literature review. The possible answers to the multiple choice questions were structured related to the performance measurement framework suggested by Kaplan and Norton [1996] and the most common KPIs for PD by Griffin and Page [1996]. An 'Other' checkbox provided the respondents with the opportunity to include KPIs more specific to GPD. For the open-ended questions in the survey, categories were developed to summarise the answers to these questions and allow for the variable results to be grouped under multiple headings. The categories were developed after the two studies were complete and all data was gathered to ensure the data was not confined. A mixture of quantitative and qualitative methods to data collection was adopted for the interviews. The interviews were semi structured and face-to-face with each lasting between 60-100 minutes. During the interview process, the development of a predetermined coding scheme was necessary. The six interviews that were recorded were transcribed. Following this, the transcriptions were applied to the previously developed coding scheme and amendments and further categories were added to the scheme where necessary. To allow for the quantification of data from the interviews, it was indicated each time a particular word or phrase was mentioned that was related to the categories. A number of the sub-categories contained dropdown lists in the coding scheme to help with the grouping of data during analysis. When a KPI was suggested by two or more of the interviewees, which fell under the 'Other' category, a new KPI for analysis was created.

4. FINDINGS

4.1 Key challenges and success factors for GPD

A coding scheme was used to collect the data concerning the key challenges and success factors during the interviews. The interviewees were unaware of the challenges and success factors found in literature prior to the interview, encouraging them to think independently regarding their motivations for GPD. Communication was the most mentioned key challenge and was addressed by all of the interviewees. The factor was mentioned 36 times in total, which is 25 times more than the next factor, cultural differences. The remaining factors from literature were not discussed so much during the interviews. The results for the key success factors were similar in that there was one which was mentioned far more than the others. Collaborative culture was mentioned on 23 separate occasions during the interviews. It was addressed by all of the interviewees; in contrast to the other success factors. Similar to communication, collaborative culture was by far the most mentioned factor. Collaborating across borders is a necessity for GPD. One of the main consistencies throughout the interviews was the agreement of the need for a collaborative culture during a project. Second to collaborative culture was core competence, which was mentioned by five of the interviewees, totaling to 12. A key area for discussion relating to this factor was the importance of aligning individual expertise to the particular task outlined within a project. This was identified as a crucial criterion for success in GPD.

4.2 Key Performance Indicators for GPD

The results from the survey and interviews form the analysis for the KPIs. The results of the KPIs used by the participating organisations for measuring the performance of GPD from the survey are illustrated in Figure 2. A total of 17 KPIs (including 'Other') are used. The top three most common KPIs are development cost, customer satisfaction and project vs. time plan. Development cost was used by 10 different organisations. When considering the number of useable responses to this question; 83.3% of the respondents indicated they use or have used this KPI in the past. Furthermore, customer satisfaction has a 75% indication rate and project vs. time plan 66.6%. A number of the 'Other' KPIs included flexibility, cost per hour and cost of external development cost against internal development cost. The results from the interviews for the KPIs used in GPD are displayed in Figure 3. The interviewees mentioned a total of eight KPIs from those found during Griffin and Page's study [1996]. The 'Other' category generated a total of 15 different KPIs. The individual KPI mentioned the most, outside of the 'Other' category, was sharing of knowledge and expertise, being mentioned a total of 10 times by three different interviewees. The most notable result from Figure 3 is the inclusion of the new KPI 'Communication capability'. Whilst collecting the data from the interview, Communication capability was mentioned seven times by four different interviewees as an indicator for measuring performance, which resulted in a new category being generated. Based on the statements made by the four different interviewees, Communication capability in the context of measuring performance in GPD is defined by the author as *"An external collaborator's ability to communicate (or not have the* *need to communicate with a partner) before, during and after the process of GPD".* Communication capability was the third most mentioned KPI behind sharing of knowledge and expertise with 10 and customer satisfaction, 8. A further noticeable pattern is the amount of times a different KPI was mentioned that fell under 'Other'. However, this was expected by the author as the structure for coding the KPIs was based on data gathered for measuring performance in PD rather than GPD. This generated 'Other' KPIs such as Follow up interest from customer, Company popularity, Collaborators' ability to think independently and Established lines of communication, to name a few. The total amount of 'Other' KPIs mentioned for measuring performance in GPD across the surveys and interviews was 22.

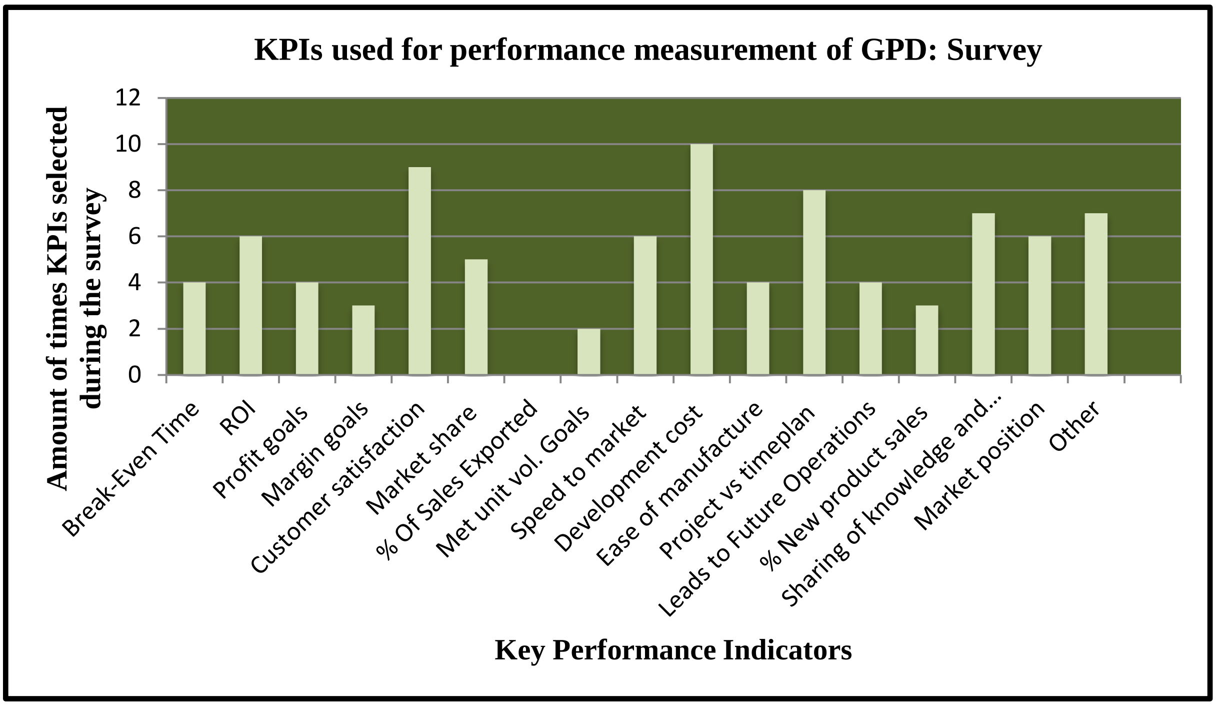

Figure 2 KPIs used in GPD: Survey

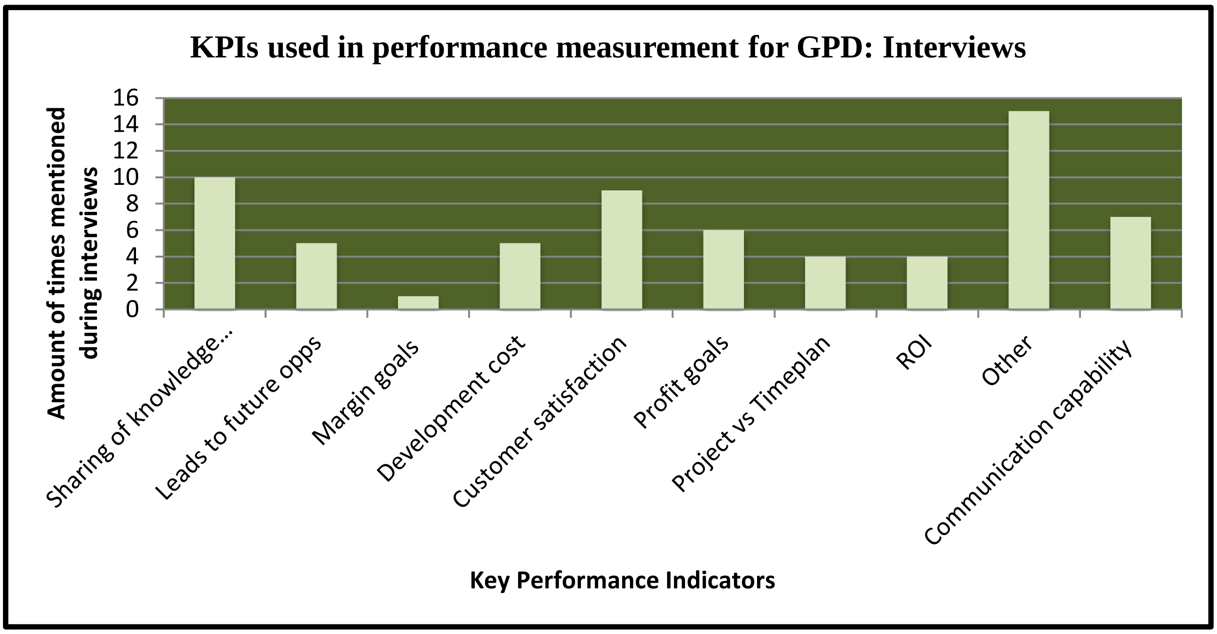

Figure 3 KPIs used in GPD: interviews

The next step of analysis involved categorising the KPIs found for GPD under the performance dimensions suggested by Kaplan and Norton [1996]. Before this was analysed, the KPIs that fell under the 'Other' category for the survey and interviews were divided among the performance dimensions where possible. Also, given the amount of times mentioned and the current unfamiliarity of ‘Communication capability’, the KPI was considered as a performance dimension for the following analysis. This exercise resulted in six of the ‘Other’ KPIs being distributed within the five performance dimensions, which left a requirement for the ‘Other’ category to remain among the dimensions. The categorising of the ‘Other’ KPIs was conducted solely by the main author. The results for grouping the KPIs for GPD from the survey and interviews under the performance dimensions are displayed in Figure 4. The results from both studies follow a similar pattern. The survey scores slightly higher along each of the performance dimensions, apart from communication capability as this dimension was irrelevant for the survey results. This can be explained due to the number of participants being greater for the survey. The KPIs that fall under the internal dimension for the survey portray the largest difference in results between the two studies. When considering the results for the interviews, learning and growth was mentioned the most times with 18. The sharing of knowledge and expertise KPI influences this high result as it was mentioned 10 times among the interviewees. Furthermore, the consistency of the results for the ‘fifth’ performance dimension: Communication capability against the other four dimensions suggests that its inclusion to the framework is justified. The ‘Other’ category only scored 6 during the interviews and 7 during the surveys. However, it is interesting to take a different angle of analysis for the ‘Other’ category. Although the KPIs within this dimension were not mentioned as often as the other dimensions; the amount of individual KPIs that fit within the ‘Other’ category was 6 during the interviews and 7 during the survey. The other dimensions contained the following number of individual KPIs: Financial – 4, Customer – 2, Internal – 4, Learning and growth – 3 and Communication capability – 4. Therefore, although the ‘Other’ KPIs were not mentioned as frequently as the KPIs within the different dimensions, they hold the most amount of individual KPIs within the ‘Other’ category.

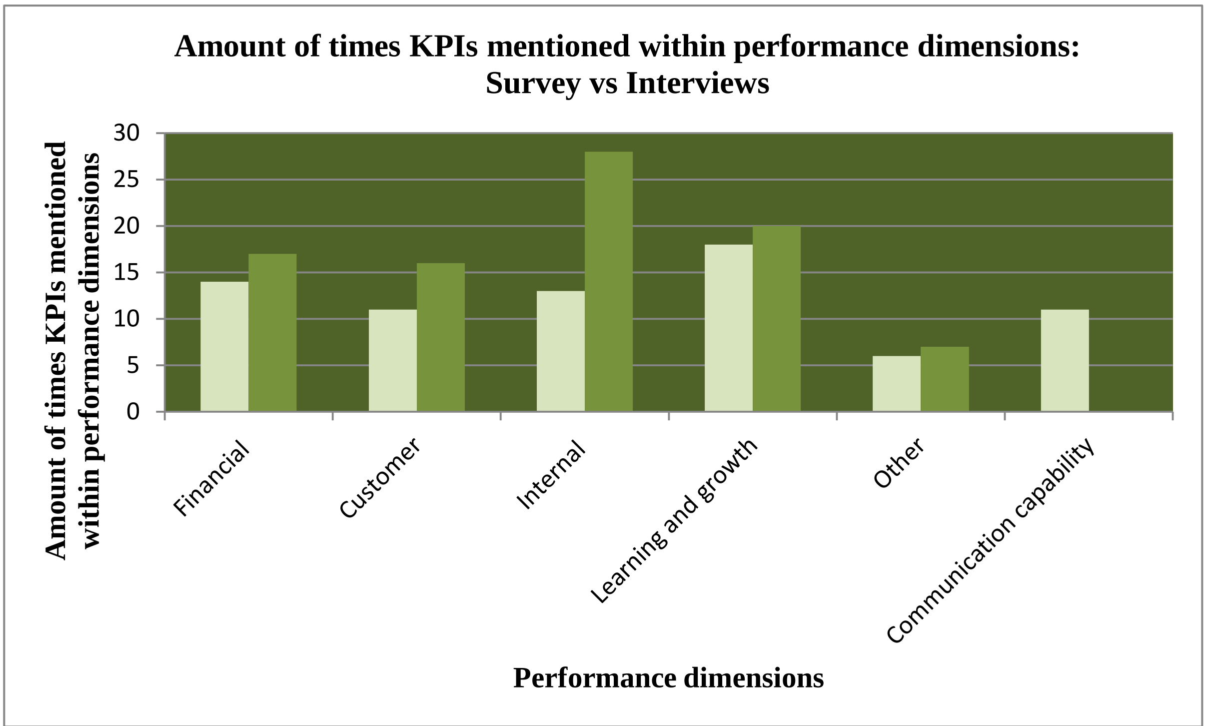

Figure 4 KPIs for GPD within performance dimensions

The number of KPIs that could not be categorised under the performance dimensions indicate that the performance measurement framework suggested by Kaplan and Norton [1998] is insufficient to facilitate the KPIs generated for GPD, and the need for further performance dimensions is evident.

3 CONCLUSION

The paper investigated key performance indicators for global product development. From the literature the main challenge and success factors for GPD established an understanding of an organisation’s motivation for GPD. Kaplan and Norton’s [1998] performance measurement framework was identified as a method for framing KPIs. This proposed framework’s for performance measurement in PD was used to categorise the challenge and success factors for GPD. This indicated a gap in the literature between the performance measurement frameworks for PD and the challenge and success factors for GPD and demonstrated a need for further studies. Hence a survey with 28 companies and 6 interviews were conducted to further investigate KPIs for GPD. The organisation's current method of performance measurement collected from these two empirical studies further highlighted the gap and recommendations for further performance dimensions within the framework. Hence, current frameworks for KPIs have yet to incorporate categories that are relevant for GPD. By building on previous work in the area and utilizing aspects of established methodologies from performance measurement in PD, this paper has highlighted the need for further dimensions in current performance measurement frameworks. Furthermore, KPIs for measuring performance in GPD have been presented.

ACKNOWLEDGMENTS

The authors would like to thank the participating companies throughout the completion of the surveys which contributed towards the results presented in this paper. Secondly, special thanks must go to the interviewees for taking the time to participate in the study.

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Appendix 5.2 Paper II

Reference: Taylor, T. P., Ahmed-Kristensen, S. 2014. "The applicability and coherence of key performance indicators in global product development." *Proceedings of the 13th International Design Conference – DESIGN*, 2014, Dubrovnik, Croatia.

Authors	Taylor, T. P., Ahmed-Kristensen, S.
Title	The applicability and coherence of KPIs in GPD
Published in	Proceedings of the 13th International Design Conference, DESIGN 2014, Dubrovnik, Croatia.
Research aim	For successful performance measurement, critical factors influencing success should be understood and KPIs selected accordingly. There is a need to understand how KPIs in GPD cohere with factors influencing success.
Research stage	Design Research Methodology: Research clarification → Descriptive study I.
Research approach	Two surveys were conducted: the first with 28 companies; and the second with 16 companies to identify KPIs used in GPD for monitoring and measuring key challenges and motivations in order to assess coherence.
Summary of findings	A review of literature (59 articles) revealed the lack of studies that investigate the selection and use of KPIs at an operational level in GPD projects. From the empirical studies, the importance of key challenges in GPD, such as cultural differences and communication, was highlighted. However, few KPIs were stated by participants for monitoring the influence of these on success. In contrast, KPIs were stated for each of the motivations for GPD, which confirms findings from literature where approaches to performance measurement in the context of PD are predominantly goal-oriented without consideration towards the challenges and their influence on success.
Contribution	The paper contributes to the thesis by highlighting that goal-oriented approaches to selecting KPIs do not provide sufficient basis to select KPIs that monitor key challenges in GPD. An in-depth understanding towards the selection and use of KPIs at an operational level in GPD projects is required and is lacking in literature. This understanding provides the basis for the development of a support method that supports the selection of KPIs in GPD.

INTERNATIONAL DESIGN CONFERENCE - DESIGN 2014
Dubrovnik - Croatia, May 19 - 22, 2014.

THE APPLICABILITY AND COHERENCE OF KEY PERFORMANCE INDICATORS IN GLOBAL PRODUCT DEVELOPMENT

T. P. Taylor, S. Ahmed-Kristensen

Keywords: Performance, Measurement, Global Product Development.

1. Introduction

Selecting and applying Key Performance Indicators (KPIs) in conventional Product Development (PD) is challenging and is compound by Global Product Development (GPD) [Taylor and Ahmed-Kristensen, 2013]. The added challenges of globally re-locating parts of PD such as communication difficulties, IP rights and aligning goals and expectations [Hansen and Ahmed-Kristensen, 2012], together with motivations to reduce costs, increase customer base and gain access to new competencies [Christodoulou, 2007], make it difficult to know which KPIs should be selected and applied when measuring the success of a GPD project [Canez *et al.*, 2000, Dabhilkar *et al.*, 2008]. A recent trend, given the sacrifices and risks associated with GPD, has seen the practice of outsourcing and offshoring parts of PD reversed and many companies decide to localise rather than globalise PD [Eppinger, 2009]. Previous studies have shown that the decision to globalise PD is often made on an ad-hoc basis [Hansen and Ahmed-Kristensen, 2011] without clear understandings of the potential benefits or risks from such decisions [Dabhilkar *et al.*, 2008, Kitcher *et al.*, 2013]. Performance measurement and monitoring, which provides accurate feedback on the efficiency and effectiveness of a process, is an established practical method to support decision making and achieve sustainable business success [O'Donnell and Duffy, 2002, Nenadal, 2008, Neely *et al.*, 2000]. Furthermore, the inclusion and application of a Performance Measurement Framework (PMF) during the process of GPD has been highlighted as a key element to ensure learning's are identified and incorporated in the decision making process [Tripathy *et al.*, 2011, Hansen and Ahmed-Kristensen, 2012, Canez, 2000]. The Balanced Scorecard (BSC) by Kaplan and Norton [1992] and the more recent Performance Prism [Neely *et al.*, 2002] present two of the most applied PMFs to date. However, it is difficult to assess if these are reliable for GPD. A study by Jiang and Qureshi [2006], which included a review of 168 articles from the outsourcing literature, concluded that there were no studies with fully reliable quantitative indicators of performance. In contrast, similar reviews [Griffin and Page, 1996, Cooper, 1998] identified large numbers of reliable KPIs used by companies within the field of conventional PD. Given the opportunities and challenges that arise from GPD, the authors argue that it is not always adequate to simply use existing PMFs and KPIs that are applied in conventional PD for GPD [Taylor and Ahmed-Kristensen, 2013]. This paper investigates the coherence between strategic level goals and challenges and the operational level KPIs in GPD. Furthermore the applicability of the KPIs in the context of GPD is investigated. In doing so, the paper draws conclusions from a systematic review of literature consisting of 59 articles, presents the results from a survey with 28 respondents from industry and reports on an exercise carried out by 16 companies at a recent workshop, where strategic level goals and challenges for GPD were validated.

2. Literature review

2.1 Global Product Development

GPD is the globalisation of tasks and activities throughout PD, from the start of the process of the fuzzy front-end and research and development to manufacturing and maintenance activities [Hansen and Ahmed-Kristensen, 2012]. The globalisation of tasks may involve outsourced engineering work along with captive offshore engineering facilities [Eppinger and Chitkara, 2009]. Outsourcing is defined as: a different company owns the foreign organisational unit where the relocated work is completed. Offshoring is defined as: the company in question owns the foreign organisational unit where the relocated work is completed. A survey that PD specialists PTC recently conducted in BusinessWeek Research Services [2006] of over 1000 engineering managers at manufacturing organisations found that 70% of the companies were either in the process of executing or were already executing GPD. Table 1 illustrates the classified strategic goals and motivations behind GPD from four independent studies in literature, which are the results from case studies and surveys that focused on the PD and manufacturing industry. The results have strong similarities and the research in this area is maturing. The authors categorised the goals within three dimensions, namely; financial benefits, operational benefits and market benefits (shown in the right column in table 1). Three of the goals from three of the independent studies could not be categorized and are within the 'Other' category; Risk mitigation, Fewer regulations and Competitive advantage. The importance and relevance of each of the goals vary depending on the context.

Table 1 Classified and categorised goals for GPD from four independent studies.

Source:	***Hansen, Ahmed-Kristensen 2012***	***Christodoulou et al 2007***	***Denmarks Statistics 2011***	***Taylor, Ahmed-Kristensen 2013***	**Categorised**
Goals for GPD	Lower costs (salaries) Lower project costs Lower logistic costs	Cost	Reduction of labour costs Reduction of costs other than labour costs	Cost reductions	***Financial benefits***
	New competencies Resources with knowledge of local market Increasing innovation heights Better resources Scalability and flexibility of resources	Access to resources Innovation and learning Agility	Lack of qualified labour Access to specialised knowledge/technologies Improved quality or introduction of new products	Access to new competencies and resources Increase customer base Flexibility and scalability	***Operational benefits***
	Close to local market knowledge Close to local suppliers, customers and competitors	Customer service	Access to new markets Reduced delivery times	Reduce time to market	***Market benefits***
		Risk mitigation	Less regulations	Competitive advantage	***Others***

Companies face difficulties when globalising parts of PD. Previous studies highlight seven key challenges: 1) Cultural differences 2) Knowledge sharing 3) Communication 4) Documentation 5) Lack of a common vision 6) IP rights and security 7) Standardising tools and processes [Hansen and Ahmed-Kristensen, 2012]. Similar to the goals, the challenges vary in importance depending on the context, and the risks they pose can directly impact the decision rationale and the eventual success of

GPD. The majority of the research on outsourcing has focused on success stories and best practice, with companies reluctant to publicise when decisions made during the process failed to work out as planned. Studies by Hansen and Ahmed Kristensen [2012] found that the case companies investigated had only considered the positive impacts of moving abroad, leaving few processes in place to handle the difficulties. The solutions to these difficulties were implemented on an 'as needed' basis and the consequences had not been evaluated. In addition, the companies were observed to switch strategies of offshoring and outsourcing. A number of case studies by Baithelemy [2003] highlight the need to understand the hidden costs involved with outsourcing. The hidden costs impact the success of GPD and challenge the decision rationale. While successful outsourcing requires spending on vendor searching, management costs or training to name a few, these costs can potentially turn successful outsourcing efforts into a failure. From the case studies, Baithelemy concludes that while carefully selecting the vendor and aligning expectations and clearly defining a set of performance measures may be costly, such expenses are necessary to reduce the impact of the hidden costs. The cases illustrate the importance for management to receive accurate feedback on the performance of GPD projects and a need for additional quality procedures. Accurate feedback provides the grounds for decisions to be made as illustrated in the Global Decision Making framework [Hansen and Ahmed-Kristensen, 2012]. In practice a company is likely to start slow, outsource a part of a process, assess the performance, and then decide on how to proceed [Jagdev *et al,*. 2005, Neely *et al.*, 1997].

2.2 Performance measurement

There are many descriptions and definitions of what constitutes performance and the measurement of performance in literature. A commonality among researchers, which is how performance is defined in this paper, is to define performance as the effectiveness and efficiency of a process with the purpose of achieving a fixed objective or set of goals [Kaplan and Norton, 1992, O'Donnell and Duffy, 2005, Neely *et al*., 2002]. Efficiency is defined as the amount of resources used in relation to those available for the process, while effectiveness is defined as the attainment of objectives or goals relative to the process. Measuring performance is often carried out with KPIs, which in engineering design are defined as quantifiable measurements that help an organisation measure the success of critical factors [Gries and Restrepo, 2011]. The KPIs vary in nature and are categorised by the designers of the Balanced Scorecard as: Leading indicators – that identify factors affecting a process and; Lagging indicators – that identify events that have taken place. The complexity and coherence between the KPIs, goals and risks are crucial to ensure successful measurement and feedback on the process [O'Donnell and Duffy, 2005].

2.3 KPI applicability

Studies in literature, which explore the use of KPIs in conventional PD, have reported large amounts of measures used in industry such as *Development cost, Project lead time, Customer satisfaction,* etc. [Kitcher *et al.*, 2012, Palm and Whitney, 2013]. However, there is a lack of research reported on KPIs for GPD and those reported are often not defined to a level of granularity that can be applied at an operational level and it is challenging to understand how the KPIs are actually measured [Jiang and Qureshi, 2006]. Taisch *et al,*. [2011] propose a framework, with the example KPI: *Number of identified customer needs*. The framework provides a systematic approach towards describing how the given KPI should be measured in practice, which enhance KPI applicability. They propose that each KPI used for a given project should follow the framework; however, the decision maker may focus their attention on feedback from the most relevant KPIs for their context. When considering successful performance measurement, it is important to distinguish between the process of creating a PMF, i.e. selecting the right measures, and the actual output of the process of performance measurement, i.e. the measurement. This paper focuses on the process of creating a PMF. Neely *et al,*. [2000] propose six criteria for successful performance measurement system design: 1) Should be derived from companies strategy; 2) The purpose of the measure must be made explicit; 3) Data collection and methods of calculating performance must be clear; 4) All stakeholders must be involved in the selection of the measures; 5) Take account of the organisation and; 6) the measures should change as circumstances change. The first criterion is arguably most important and is mentioned throughout literature. The remaining criteria link strongly towards the use and validity of the PMF. There are many examples in literature where PMFs have had a negative impact on organisational behaviour [Neely *et al.*, 2000]. The underlying issue with the cases is the lack of coherence between the strategic level goals and the operational level KPIs. For a successful PMF for GPD, it is important that this coherence is present to avoid the negative impact on organisational behaviour.

2.4 Current frameworks

Two of the most well documented PMFs are the Balanced Scorecard (BSC) [Kaplan and Norton, 1992] and The Performance Prism [Neely *et al.*, 2002]. Kaplan and Norton [1992] state the BSC framework represents a balanced approach to measurement as it considers financial and non-financial factors from four perspectives: Customer, Internal, Financial, Learning and growth. The framework is widely used in industry ranging from the financial to the healthcare sector. However, the framework has been analysed and evaluated and when considering PD, authors argue that the framework is difficult to implement in an organisation that has a diverse and dynamic environment [Molleman, B. 2007]. O'Donnell and Duffy [2005] raise concerns regarding the practicality of the framework for the PD process. The framework does not fully support coherence between the business level goals and the operational level KPIs. Furthermore, previous studies by the authors of this paper highlighted a need for the inclusion of further perspectives than the four recommended when considering performance measurement in GPD [Taylor and Ahmed-Kristensen, 2013]. The Performance Prism is a more recent framework with a strong focus on identifying and mapping stakeholder's needs. In addition to the BSC, The Performance Prism ensures the goals and measures selected are prioritised and weighted accordingly. However, the framework offers little about how the KPIs should be realised [Tangen, 2004]. The Performance Prism is a framework that focuses on the process of creating a PMF. The two frameworks are excellent examples of strategic level tools for the design of a PMF. However, they rarely help with the practical realisation and applicability of KPIs at an operational level.

2.5 Summary of literature

Table 2 presents a summary of the literature on performance measurement in GPD. The summary consists of 59 articles, which are analysed in four independent categories, namely: Field of research, Method, Proposed model and the Industry sector to which they apply. The summary not only illustrates the gap in literature in performance measurement in GPD, but also the gap in performance measurement at an operational level in GPD. The findings support those of Tangen [2004], where the study highlighted the need for performance measurement to be operationalised. As illustrated in Table 1, the strategic level goals and objectives for GPD are maturing. However, the current frameworks and summary of literature focusing on performance measurement in GPD highlight the lack of research on operational level performance measurement in GPD. Furthermore, there is a need for a challenge based approach, when considering the selection and the applicability of the KPIs. The following section presents how the authors intend to build on these findings.

Table 2 Summary of literature (GPD = Global Product Development, PM = Performance Measurement, OD = Other Discipline).

Field of research	GPD (GPD+PM)	PD + PM	OD + PM
No. of articles	**19 (9)**	**30**	**10**

Method (primary)	Survey	Case studies	Analysis of literature
No. of articles	**13**	**27**	**19**

Proposed model	Descriptive	Prescriptive	n/a
No. of articles	**37**	**14**	**8**

Industry	PD	Manufacturing	Other
No. of articles	**18**	**23**	**18**
Total number of articles	**59**		

3. Methodology

3.1 Research aim

The aim of the research was to investigate the coherence between the strategic level goals and challenges and the operational level KPIs in GPD. Furthermore, the applicability of the KPIs was investigated. This was two-fold: first the literature review categorised the strategic level goals in GPD and highlighted the gap in operational level performance measurement, presented in Table 1 and Table 2. Second, the empirical studies in the following sections investigate the KPIs used in GPD, relative to the strategic goals and challenges.

3.2 Research approach

An independent survey and an exercise at a workshop on GPD formed the empirical investigations. The survey was collected for a previous study [Taylor and Ahmed-Kristensen, 2013] where results were analysed and compared with the four perspectives of the BSC. This paper builds on the initial survey results by analysing the coherence between the KPIs and the strategic goals, and the applicability of the KPIs at an operational level. The exercise further contributes towards how managers measure performance relative to a set of defined strategic goals and challenges. The knowledge gained from the survey was used as a basis to design the data collection exercise for the workshop.

3.3 Participants

The survey was distributed to 100 companies and 28 completed responses were received. 27 of the companies were Danish and 1 from the UK. The respondents consisted of 19 large, 2 medium and 7 small companies from the manufacturing or PD sector [Taylor and Ahmed-Kristensen, 2013]. The participants of the exercise were attendees of an industrial workshop with a focus on GPD.The participants at the workshop were professionals with previous experience in GPD. Information on the size, industry sector and position in the company of the respondents are presented in table 3.

Table 3 Size of participating companies for the exercise

Size:	Small	Medium	Large
No. of participants:	6	5	6

Industry:	Product dev.	Energy	Engineering	Innovation	Business dev.	Electronics
No. of participants:	8	5	1	1	1	1

Position:	Founder	Top Mgt.	Engineer	Consultant	Project Mgt.	Offshoring Mgt.	Designer
No. of participants:	3	3	3	1	5	1	1

3.4 Data collection

3.4.1. The survey

The survey was kept short (between 7 to 10 minutes) to maximize the response potential. Multiple choice questions were designed where possible to help with the analysis of data, these included the option *other* to allow for the collection of responses outside of the choice. The respondents were asked to list their goals and motivations for GPD. Following this, they were asked to select the KPIs used for measuring the performance of GPD. The results from the questions were categorised by the authors. The categorised KPIs were aligned under the relevant goals for GPD. In some cases there was not a clear link between the goal selected and the KPI proposed for measuring the goal by the respondents. In this case, the authors realigned the KPI under the goal it was linked with. The realignment was then validated with a colleague (who had experience with the topic) using a kappa analysis, which indicated a strong validation scoring: 0.78.

3.4.2 The exercise at the workshop

The methodology was kept as close to the survey as possible to allow for the comparison of data sets. The participants were provided with brief instructions of how to complete the exercise beforehand, and no KPIs were presented to avoid influencing their response. Each participant was asked to think of a past or present GPD project that they were involved with. For the project they were asked to follow the steps presented in Figure 1. First, the participants were asked to select and prioritise the goals and challenges for GPD (Step one). In addition to the survey, the participants were asked to state their strategies towards achieving the goals and avoid the challenges (Step two) in an attempt by the authors to strengthen the applicability of the KPIs stated in the following step. The final step (Step three), the participants were asked to state the relevant KPIs used to measure the goals and challenges.

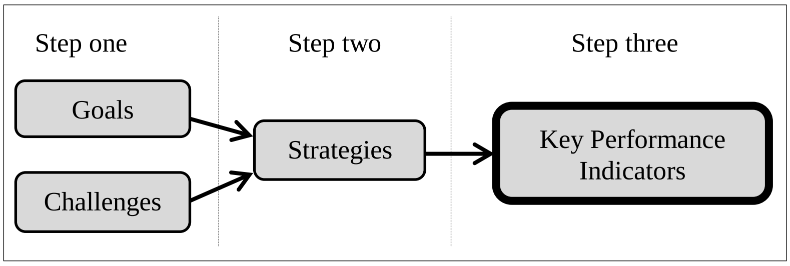

Figure 1 Three step approach to completion of the exercise.

The exercise produced two sets of data: KPIs used for measuring the goals for GPD and KPIs used for monitoring the challenges and minimizing risk for GPD. The KPIs were put into two categories: *measurable* and *immeasurable*. The *immeasurable* KPIs were not analysed in this paper. In some cases, there was not a clear link between the goals or challenges selected and the KPI proposed. In these cases, the authors realigned the KPI under the goal or challenge it was linked with.

4. Key findings

The results from the survey and exercise form the analysis of the coherence between the strategic level goals and the operational level KPIs applied in GPD. From the survey, each of the responses for the goals, and KPIs for measuring the goals of GPD, were analysed for frequency of response. From the exercise, each of the responses for the goals and challenges, the strategies towards achieving the goals and challenges, and the KPIs used for measuring the goals and challenges, were analysed for frequency of response.

4.1 The survey: KPIs relative to the goals for GPD

From the survey, the following key observations were made, which are illustrated in Table 4:

- *Cost reduction* was the most frequent goal for GPD, as selected by the respondents (16 response), and *Reduce time to market* the least selected (2 responses).

A total of 18 KPIs were stated relative to the five goals for GPD. From the KPIs, *Customer satisfaction* was the most stated KPI (10 responses), with *Development cost* and *Project Vs. Timeplan* the second and third most selected KPIs respectively. There were a total of 7 KPIs for measuring the most selected goal of *Cost reductions*.

Table 4 KPIs relative to strategic level goals for GPD with frequency mentioned: Survey

Goals	Freq.	Coded KPIs	Freq.
Access to new resources	8	***Leads to Future Opps***	3

		% New product sales	2
		Share knowledge and expertise	5
Cost reductions	16	***Break-Even Time***	3
		ROI	5
		Margin goals	2
		Development cost	9
		Profit goals	3
		Cost pr. hour	1
		cost of ext. vs. internal dev. cost	2
Reduce time to market	2	***Speed to market***	6
		Ease of manufacture	4
		Project vs. timeplan	8
Flexibility and scalability	8	***Market position***	5
		Flexibility	4
		Met unit vol. goals	2
Increase customer base	3	***Customer satisfaction***	10
		Market share	4

4.2 The exercise: KPIs stated relative to the goals for GPD

From the exercise, the following key observations were made in relation to the selected goals for GPD and the KPIs for measuring them (Table 5):

- *Access to new resources* and *Reduce time to market* were the goals with the highest priority. The goal with the lowest priority was *Increase customer base*.
- An additional category was created: *Risk mitigation*, as this was a goal mentioned twice by two separate participants.

The frequency of the strategies mentioned was not included in Table 5 as all strategies were only mentioned once, with the exception of *Use of external expertise* and *Outsource tasks,* which were mentioned 4 and 3 times respectively. In total there were 44 KPIs collected that the participants stated as measures for the goals for GPD. 28 of the KPIs were considered to be *measurable* by the authors. These KPIs were then categorised and those that did not cohere with the selected goals were realigned, which resulted in a total of 15 KPIs relative to the goals (Table 5). *Project lead time* was the most frequently mentioned KPI with 8, which was a KPI for measuring the goal *Reduce time to market*. The frequency of KPIs mentioned for each goal was relatively balanced, with the exception of *Reduce time to market*. Examples of *immeasurable* KPIs were: 3rd party review, milestones, management and coordination. These were considered to be strategies to achieve the goal rather than measure performance towards the goal and were not included in the analysis.

Table 5 KPIs and strategies relative to strategic level goals for GPD with frequency mentioned: Exercise

Goals	Freq.	Coded strategies	Coded KPIs	Freq.
Access to new resources	9	Development of competencies	***No.of new projects***	2
		Quality service		
		Process indicators	***No. of new alliances***	2
		Partner screening		
Cost reductions	8	Use external expertise	***Output Vs. resource allocation***	1
			Development cost	2
			Labour cost	1

Reduce time to market	9	Increase resources	***Project lead time***	8
		Process control		
		Increase no. of designers		
		Platform strategies		
		Outsource tasks		
		Use external expertise		
		Process control	***Project plan status***	2
		Outsource tasks		
		Partner screening	***Clarity of requirements***	1
Flexibility & Scalability	8	Variation of product family	***Capability of supplier delivery***	2
		Identify correct partner		
		Use external expertise	***Capability to take similar work***	1
Risk mitigation	3	Reduce iterations	***No. of delays in project plan***	1
		Process control	***No. of solved work packages***	1
Increase customer base	2	Close to customers	***No. of new customers***	1
		Variation of customers	***No. of sales from new location***	1
		Use external expertise	***Quality***	2
		Outsource tasks		

4.3 The exercise: KPIs stated relative to the challenges of GPD

From the exercise, the following key observations were made in relation to the selected challenges for GPD and the KPIs stated for measuring them (Table 6):

- *Communication* and *Cultural differences* were the challenges with the highest priority, mentioned 16 and 10 times respectively.

The frequency of the strategies and KPIs mentioned was not included in Table 6, as all were only mentioned once, with the exception of the KPI *Frequency of process problems*, which was mentioned twice. Furthermore, there were no strategies or KPIs mentioned by the participants for monitoring the challenges and minimising the risks of *Documentation* and *Lack of common vision*. There were almost 50% fewer KPIs in Table 6 than in Table 5. 41 KPIs were considered to be *immeasurable* by the authors compared to 8 that were *measurable*.

Table 6 KPIs and strategies relative to strategic level challenges for GPD with frequency mentioned: Exercise

Challenges	Freq.	Coded strategies	Coded KPIs
Communication	16	Face-to-face meetings	*No. of goals met on time*
		Clear goals	*No. of agreements kept*
		Status reports	*No. of problems during project*
		Multimedia based communication	*Frequency of communication problems*
Cultural differences	10	Cultural exchange awareness program	*Employee feedback on job stability*
IP rights	5	Patent application	*No. of patents*
Knowledge sharing	7	Common document base	*Availability of documentation*
Standardising tools and processes	5	Mutually clear process	*Frequency of process problems*
Documentation	*No strategies or KPIs mentioned*		
Lack of common vision	*No strategies or KPIs mentioned*		

4.4 The implications

The results in Table 4 and 5 propose a balanced set of KPIs for each of the goals. However in comparison, when considering monitoring and measuring the challenges in GPD, Table 6 contains fewer KPIs despite the clear importance of the challenges *Communication* and *Cultural differences* in GPD. This is confirmed by literature where focus on KPIs is on the goals of GPD with little consideration of the additional challenges as a result of GPD. Although participants of the survey and exercise stated KPIs for measuring the goals, the applicability at an operational level was weak and there were many KPIs that the authors deemed to be *immeasurable* when considering the KPI description framework [Taisch *et al.*, 2011]. Furthermore, the coherence between the KPIs stated and the goals and challenges selected was absent in a number of cases. For example, *Market position* was a KPI stated for measuring the goal *Flexibility and scalability* in the survey and *Quality* as a KPI stated for measuring the selected goal *Increase customer base* in the exercise. When considering criteria 1 in the success criteria for performance measurement [Neely *et al.*, 2000], which is arguably the most important, the criteria states: The measures should be derived from companies strategy. However, given the categorisation and realignment process by the authors of the KPIs, the coherence between the strategic level goals and challenges and the operational level KPIs is lacking.

4.5 Limitations

Although all participants of the workshop had experience in GPD; their level of experience, in terms of number of years or the complexity of tasks that they outsourced or offshored, was unclear.

5. Conclusion

With the systematic review of literature and two independent empirical studies, this paper has investigated the coherence between strategic level goals and challenges and the operational level KPIs in GPD. Furthermore, the applicability of these KPIs in the context of GPD was investigated. From the analysis of literature (59 articles), the gap between operational level KPIs and strategic level goals and objectives was made explicit and a lack of research on KPIs for GPD was apparent. As a result of the analysis of literature, there were three key implications:

- Only 9 articles were found out of 59 that focused on performance measurement in GPD.
- Only 1 of these articles focused on performance measurement in GPD at an operational level [McKay *et al*., 2013] and the remaining at a strategic level.
- Only 14 articles proposed prescriptive models, which address the practicalities of measurement and offer guidance for the actual selection and implementation of measures.

From these results, we conducted a survey with 28 respondents and an exercise with 16 companies. KPIs from a goal oriented approach were presented that are used in industry for measuring the performance of GPD. Furthermore, building on previous studies [Taylor and Ahmed-Kristensen 2013] a challenge oriented approach to performance measurement was presented. The goals and challenges for GPD were validated through the exercise with the creation of one additional goal: risk mitigation. The results from the two studies imply that companies feel the goals and challenges are relevant and important for GPD, however when considering the applicability and coherence of the KPIs with these goals and challenges at an operational level, there is a lack of understanding of how they should be measured and monitored. By building on previous research in the area and adapting key aspects of methodologies from performance measurement, this paper has: highlighted a lack of research on KPIs for GPD at an operational level; presented KPIs used in industry for measuring performance of GPD at an operational level; and highlighted a lack of applicability and coherence with these KPIs, especially when considering a challenge based approach to measurement. Further work should focus on linking KPIs in GPD to current processes and procedures in a company at an operational level.

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Appendix 5.3 Paper III

Reference: Taylor, T. P., Ahmed-Kristensen, S. 2014. "Key performance indicators: Global product development." *Proceedings of the 21st EurOMA conference: Operations management in an innovation economy*, 2014, Palermo, Italy.

Authors	Taylor, T. P., Ahmed-Kristensen, S.
Title	Key Performance Indicators: Global Product Development
Published in	Proceedings of the 21st EurOMA conference, EurOMA 2014, Palermo, Italy.
Research aim	Selecting KPIs in conventional PD is challenging and is further compounded by GPD. An in-depth understanding towards how KPIs are selected according to key challenges and motivations in GPD at the project-level is required to serve as the basis for the development of a support method that supports the selection of KPIs in GPD.
Research stage	Design Research Methodology: Descriptive study I
Research approach	Two surveys were conducted: the first with 28 companies; and the second with 16 companies and a longitudinal case study (Company A) to collect information regarding how KPIs are selected according to key challenges and motivations in GPD projects.
Summary of findings	Many of the KPIs stated for monitoring key challenges in GPD, such as gut feeling or understanding of the situation, were subjective and difficult to measure. There was no structured method for selecting KPIs during the observed GPD project at company A. A lack of common vision and poor documentation were key challenges that resulted in project time delays. However, KPIs used for monitoring these identified the challenges late in the project and did not provide the necessary feedback required to make adjustments along the process and hence, avoid project time delays.
Contribution	The paper contributes to the thesis by highlighting the importance of selecting leading KPIs at the project-level, which monitor factors influencing success along the process. Such approach supports project managers to make necessary adjustments along the process to avoid challenges such as a lack of common vision and documentation issues, typically found in GPD projects.

Key performance indicators: Global product development.

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Abstract
The decision to globalise parts of product development is a consequence of an increasingly competitive world market. The variety of risks and opportunities as a result of the decision make it difficult for management to evaluate if global product development has been successful. This paper investigates the use of key performance indicators as an approach for measuring the success of global product development projects. With the conclusions from a survey and workshop together with observations during a global development project, the need for an alternative approach to measurement than in conventional product development is highlighted.

Keywords: Performance, Measurement, Global Product Development.

Introduction
Selecting Key Performance Indicators (KPIs) in conventional Product Development (PD) is a challenging task for project management and this is further compounded by Global Product Development (GPD). Challenges with relocating parts of PD globally such as communication barriers, Intellectual Property (IP) rights, aligning goals and expectations (Hansen and Ahmed-Kristensen, 2012), together with the desire to remain competitive by reducing costs, accessing new competencies and expertise (Christodoulou, 2007) make it difficult to assess if a project is performing or has performed successfully (Canez *et al*., 2000, Dabhilkar *et al*., 2008). Successful performance measurement requires the alignment of KPIs with strategic level objectives (Katharina and Lindemann, 2013, O'Donnel and Duffy, 2002, Neely *et al.*, 2000). The Balanced Scorecard (Kaplan and Norton, 1992) and the more recent Performance Prism (Neely *et al*., 2002) present two of the most well-documented and applied Performance Measurement Frameworks (PMF) to date. However, it is difficult to assess if these are reliable at an operational level in the context of GPD (Tangen, 2004, O'Donnell and

Duffy, 2005, Taylor and Ahmed-Kristensen, 2013). Given the additional opportunities and risks that arise from GPD, the authors argue that existing PMFs, which are applied in conventional PD at an operational level, do not fully support the GPD process and the factors effecting it. This paper investigates the coherence between KPIs selected by management with the strategic level motivations and challenges in GPD. Furthermore, building on current PMF's (Kaplan and Norton, 1992, Neely *et al*., 2002, David Parmenter, 2010), a method for the classification of KPIs in GPD is described.

The scope

When considering the Business Intelligence Model (Barone *et al.,* 2010), the focus for this paper is on middle management (operational level), whom are the project managers responsible for communicating information regarding the performance of a GPD project to top management (strategic level). Furthermore, the paper considers performance measurement in relation to the process of GPD rather than the final product.

Theoretical background

Global Product Development

GPD is the process of relocating tasks and activities throughout PD to foreign locations (Hansen and Ahmed-Kristensen, 2012). Relocated tasks and activities may include the fuzzy front end of development through to the initial testing of prototypes, which can be outsourced engineering work along with captive offshore engineering facilities (Eppinger and Chitkara, 2009). The strategic motivations for GPD are well covered in literature and can be grouped within the following categories: 1) Cost reductions 2) Access to new resources 3) Increase the customer base 4) Flexibility and scalability 5) Reduce time to market 6) Risk mitigation (Christodoulou *et al*, 2011, Denmarks statistics, 2011, Taylor and Ahmed-Kristensen, 2014). The importance of the motivations differs depending on the context. Hansen and Ahmed-Kristensen (2012) found the key challenges faced by management when globalising PD were 1) Communication difficulties 2) Cultural differences 3) Knowledge sharing 4) Lack of common vision 5) Documentation 6) Standardising tools and processes 7) IP rights and security. Similar to the motivations, the importance of the challenges differs depending on the context. A survey with over 1000 engineering managers at manufacturing organisations found that 70% of the companies had globalised parts of PD (Business week research, 2006). However a more recent study, given the risks associated with GPD, discovered that a recent trend had seen the practice of outsourcing and offshoring parts of PD reversed and many companies decide to localise rather than globalise PD (Eppinger and Chitkara, 2009). Studies by Baithelemy (2003) highlight the need to monitor performance towards the motivations when globalising PD in order to understand hidden costs such as: time, cost and quality, and the selection of relevant performance measures is necessary. Furthermore, the performance measures must cohere with the strategic level motivations and challenges to provide accurate feedback on the performance of GPD projects at an operational level (Taisch *et al.,* 2011, O'Donnell and Duffy, 2005).

Performance measurement and current frameworks

Performance is defined as the effectiveness and efficiency of a process with the purpose of achieving a fixed objective or set of goals (Kaplan and Norton, 1992, O'Donnell and Duffy, 2005, Neely *et al*., 2002). Measuring performance is carried out with carefully selected key performance indicators, which in engineering design are defined as quantifiable metrics that help an organisation measure the success of critical factors (Gries and Restrepo, 2011). Over the past few decades, research in performance measurement has predominantly been confined to PD rather than GPD. A systematic review of literature consisting of 59 articles (Taylor and Ahmed-Kristensen, 2014) further consolidates this. The following observations were made:

- Only 9 articles were found that focused on performance measurement in GPD.
- Only 1 of the articles focused on performance measurement in GPD at an operational level (McKay *et al*., 2013) and the remaining at a strategic level.
- Only 14 articles proposed prescriptive models, which address the practicalities of measurement and offer guidance for the actual selection and implementation of measures.

Studies by Griffin and page (1996) and Cooper (1998) found large numbers of indicators being used in industry such as *Development cost, Project lead time* and *Customer satisfaction*, which could be framed along similar performance dimensions such as customer based, financial success and technical performance. Similarly, the Balanced Scorecard (Kaplan and Norton, 1992) suggests grouping measures along four performance related dimensions, namely; Financial, Customer, Internal and Learning and growth. When applying this framework in the context of conventional PD, Molleman (2007) argues that the framework does not fully support the diverse and dynamic environment present in such a context. Furthermore, previous studies concluded that there is a need for further dimensions in order to include the critical factors and KPIs for GPD (Taylor and Ahmed-Kristensen, 2013, Parmenter, 2010). The performance prism (Neely *et al.,* 2002) represents a more recent PMF, which prioritises stakeholder interests when creating a PMF and selecting the relevant KPIs. However, the framework offers little about how the KPIs should be realised at an operational level (Tangen, 2004). It can be concluded that the two frameworks offer excellent examples of strategic level tools for the design of a PMF. However, they do not fully support the selection of KPIs at an operational level in GPD.

Selecting and classifying Key Performance Indicators

The method of selecting KPIs and aligning them with strategic level objectives is a critical factor when designing successful PMFs (Neely *et al., 2000,* O'Donnell and Duffy, 2005). Challenges are faced by both researchers and practitioners and there are many examples from industry where incorrect and misaligned KPIs have negatively impacted organisational behaviour (Parmenter, 2010, Neely *et al.,* 1997). A number of tools have been developed in literature to support the selection of KPIs (Taisch *et al.,* 2011, Roy *et al.,* 2000, Dziobczenski *et al.,* 2013). Tools such as the Performance Measure Record Sheet (Neely *et al.,* 1997) attempt to facilitate and stage the thought process when selecting KPIs to ensure purposeful and measurable metrics are implemented. However, when testing the Record Sheet with practitioners, there was confusion towards the implementation of the selected KPIs and the classification of the KPIs was not fully understood. In order to select KPIs that maintain validity in a given context, understanding the dynamics and classification of KPIs is key and has been a focus for much discussion in the performance measurement literature. Kaplan and Norton (1992) argue that KPIs should be classified within two categories: 1) Leading indicators – that identify factors affecting a process and 2) Lagging indicators – that identify events that have taken place. Parmenter (2010) argues that this method of classifying indicators creates confusion and it is difficult to differentiate between when a KPI is Leading or Lagging. Parmenter (2010) prefers to classify performance measures in two different categories: 1) KPIs – which focus on the most critical aspects of performance for *current and future* success and 2) KRIs – which are result indicators and are usually measured less frequently and are the *result* of actions. Clearly the two approaches towards the classification overlap and the relationship between both Leading and Lagging indicators or KPIs and KRIs when selecting and implementing metrics should be understood.

Summary of literature review

The review of literature highlighted the lack of research towards KPIs for GPD at an operational level. A commonality among authors for successful performance measurement is the requirement for coherence between selected KPIs and strategic level objectives. Given this, an alternative approach to measurement than those suggested for PD is required that incorporates the motivation and challenge factors for GPD. Furthermore, the ongoing discussion in literature towards the dynamics of KPIs suggests a need for further clarity in order to understand how KPIs can be classified in practise.

As a result of the literature review, the following research questions are investigated:

- What are the Key Performance Indicators used for measuring the success of global product development projects at an operational level?
- How do the Key Performance Indicators cohere with the strategic level motivations and challenges for GPD?

The aim of the research was to investigate KPIs used at an operational level in relation to strategic level motivations and challenges in GPD. Following this, the coherence between the KPIs and the motivations and challenges was investigated.

Methodology

Given the explorative nature of the research questions, a mixed method approach to the empirical investigations was adopted in order to provide a deeper understanding of the phenomena (Borrego *et al.*, 2013, Voss *et al.*, 2002).

The empirical investigations that followed were twofold: first a survey and complementary exercise at a workshop were conducted to investigate KPIs used in GPD relevant to strategic level motivations and challenges, second, participant observations during a GPD project at a large engineering company in Denmark provided a deeper understanding towards coherence and classification of KPIs at an operational level. Each of the empirical investigations builds on the findings from the previous.

The survey and workshop

The survey was distributed to 100 manufacturing and engineering companies in Denmark. 27 responses were received: 19 large, 2 medium and 6 small sized companies. The respondents were asked to list the company's motivations for GPD and state the KPIs used for measuring the motivations. The resulting motivations were categorised under the 6 outlined in the literature review, without a requirement for *other* categories to be developed. The resulting KPIs were categorised by the authors and aligned under the relevant motivations. The motivations and KPIs were analysed for frequency of response. For the validation of the alignment process, a kappa analysis was performed (Cohen, 1960), which indicated a strong validation coefficient: 0.78. The exercise was completed by 17 participants, which was conducted at an industrial workshop with a focus on GPD. The participants were representatives from 16 different companies from Denmark in the manufacturing and engineering sector, including: 6 large, 5 medium and 6 small sized companies. All participants had previous experience with GPD. The design of the exercise was kept similar to the survey to allow for the comparison of data. However, the respondents were also asked to state KPIs related to strategic level challenges in GPD. Furthermore, the strategies in place at the company to avoid the risk or achieve the goal bought by the challenges and motivations were noted as a step before stating the KPIs by the participants (Figure 1). As there were no *other* categories developed as a result of the survey, the partipants of the exercise were provided with the motivations and challenges based on those outlined in the literature review but with the remaining option to mention *other* motivations or challenges. The motivations, challenges and KPIs were analysed for frequency of response.

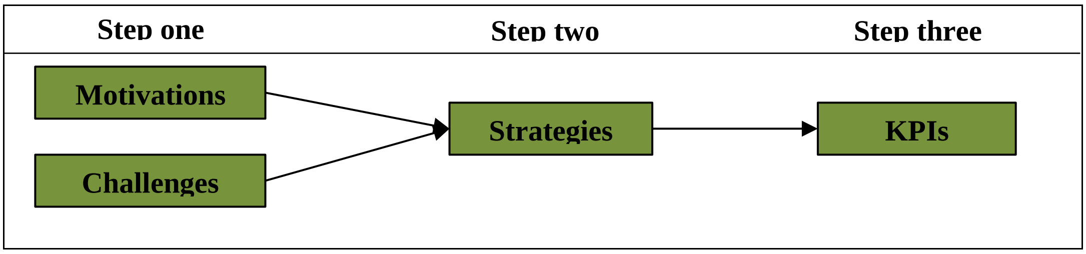

Figure 1 3 step approach to the completion of the exercise

Observations: A Global Product Development project
Observations were made during a GPD project at a large Danish engineering company with an offshore location in India. 27 meetings were observed including 7 key project milestone meetings over a time period of 4 months. The meetings lasted between 1 – 2 hours and were held using the WebEx software. The participants were experienced design engineers from Denmark and India. The role of the authors was to observe the participants during the meetings without participating. Detailed notes were kept and transferred into a coding scheme; developed as a result of the survey and exercise.

Key findings

The survey and workshop
There were 44 KPIs collected that the participants stated as KPIs for measuring the goals of GPD. 62% were considered *measurable* and the remaining *immeasurable*. Examples of the *immeasurable* KPIs were: *3rd party review*, *milestones*, and *coordination meetings*. These were considered as strategies by the authors rather than KPIs and were not included in the analysis in Table 1. When considering the KPIs relative to the motivations of GPD, the 4 most mentioned KPIs were: *Development cost*, *Project lead time*, *Project plan status* and *customer satisfaction*. The number of KPIs stated relative to the 6 motivations was balanced, with *Cost reductions* generating the most KPIs. *Cost reductions* was also the most mentioned motivation across the survey and exercise. *Flexibility and scalability* was the third most frequently mentioned motivation for GPD. However, there are a small number of KPIs stated for measuring this motivation. This implies that despite *Flexibility and Scalability* being a key motivation for GPD, the participants of the exercise and survey are uncertain of which KPIs should be selected to measure the performance towards this goal. The same conclusions can be drawn when considering the motivation *Access to new resources*.

The KPIs mentioned related to strategic level challenges were results from the exercise and comparisons with the survey were not made. A total of 39 KPIs were mentioned as KPIs for monitoring the risks bought by the strategic level challenges in GPD. 26% were considered *measurable* and the remaining *immeasurable.* Examples of *immeasurable* KPIs were: *Gut feeling, Close scrutiny and quick action to deviations* and

Risk matrix. Similar to the *immeasurable* KPIs for the motivations, many of these were considered to be strategies rather than KPIs and were not included in the analysis. The challenges *Communication* and *Cultural differences* were mentioned 16 and 10 times respectively by the participants of the exercise and indicate that they are key challenges in GPD. Given this, the number of KPIs mentioned by the participants for monitoring these challenges does not reflect the importance of the challenges. Furthermore, each of the coded KPIs was only mentioned once by the participants for monitoring the challenge, which implies that the participants were uncertain of which KPIs should be used to monitor the risks as a result of the challenges. The small number of *measurable* KPIs compared to the *immeasurable* KPIs further indicates that the participants experienced difficulties when stating KPIs for the challenges in GPD.

Table 1KPIs relevant to strategic level motivations and challenges in GPD

Survey and Exercise			
Motivations	Freq. mentioned	Coded KPIs	Freq. mentioned
Access to new resources	17	*Leads to future opps.*	**3**
		% new product sales	**2**
		No. of new projects	**2**
		No. of new alliances	**2**
Cost reductions	24	*Break-even time*	**3**
		Return on Investment	**5**
		Margin goals	**5**
		Development cost	**13**
		Cost pr. hour	**2**
		Output Vs resource allocation	**1**
Reduce time to market	11	*Project lead time*	**14**
		Project plan status	**10**
		Clarity of requirements	**1**
Flexibility and scalability	16	*Capability of supplier delivery*	**2**
		Capbility to take similar work	**1**
		Market position	**5**
Increase customer base	5	*Customer satisfaction*	**10**
		Market share	**5**
		No. of sales from new location	**1**
Risk mitigation	3	*No. of delays in project plan*	**1**
		No. of solved work packages	**1**
Exercise			
Challenges	**Freq. mentioned**	**Coded KPIs**	**Freq. mentioned**
Communication	16	*No. of goals met on time*	1
		No. of agreements kept	1
		No. of problems during project	1
		Freq. of comm problems	1
Cultural differences	10	*Employee feedback on job stability*	1
IP rights and security	5	*No. of patents*	1

Knowledge sharing	7	*Availabilty of documentation*	1
Standard tools & process	5	*Freq. of process problems*	1
Documentation	4	No KPIs mentioned	
Lack of common vision	4	No KPIs mentioned	

The coded KPIs as measures for the strategic motivations of GPD represent a relatively balanced set of KPIs and the results display coherence. However, the large number of *immeasurable* KPIs mentioned suggests there is confusion during the selection process and further investigation is required. The lack of coded KPIs as measures for the strategic challenges indicates uncertainty towards which KPIs should be selected to monitor the risks bought by the challenges. Given the small amount of *measurable* KPIs mentioned, it was difficult to analyse the coherence of the KPIs with the challenges. It is clear that practitioners feel challenges such as *Communication* and *Cultural differences* are factors that affect the GPD process and closer investigation is required to understand how they are monitored in practice. The findings are comparable with those in literature, where the focus of KPIs is on strategic level motivations or goals in conventional PD. With the additional challenges bought by GPD and the potential impacts (Baithelemy, 2003, Hansen and Ahmed Kristensen, 2012), the risks bought by the challenges must be monitored for a successful PMF in GPD.

The following observations of a GPD project was used as a method to further investigate the coherence of KPIs with strategic level motivations and challenges.

Observations: A Global Product Development project

The observations were made during a GPD project at a large Danish engineering company with an offshore engineering location in India, which was established in 2011. In 2011, key members of the Indian engineers received training in products and processes at the location in Denmark. Since 2011, less complex engineering tasks with low risks, such as the conversion of old product drawings to CAD systems were offshored to India, while larger development tasks were kept local. More recently, the Danish engineering company included the engineers in India in a larger, more complex development project, which was the focus point for the observations presented in this paper. Given the previous experience of the design engineers in Denmark, where tasks and activities sent to India did not fulfil expectations, the development project was introduced to the Indian engineers as a “PILOT” project, and coordination between the Danish and Indian team would be closely monitored for performance by the Danish engineers. The Indian and Danish team included several design engineers with a main responsible for each of the teams. The aim of the project was to improve the lifetime of an existing product through a number of possible design changes. The primary KPI for measuring the performance of the project was: *Amount of consumed resources*, which was communicated to the Indian main responsible at the beginning of the project by the Danish main responsible. Despite the project being more complex than previous tasks, it was considered by the Danish engineering team to be a relatively simple project, with the *Amount of consumed resources* expected to be kept low. The expectations, communicated by the Danish main responsible to the Indian engineers, were to propose 2 or a maximum of 3 possible solutions to the problem. The key meetings observed during the project were held on Cisco WebEx. The key challenges discussed, relative to those in the survey and exercise, are presented in Figure 2.

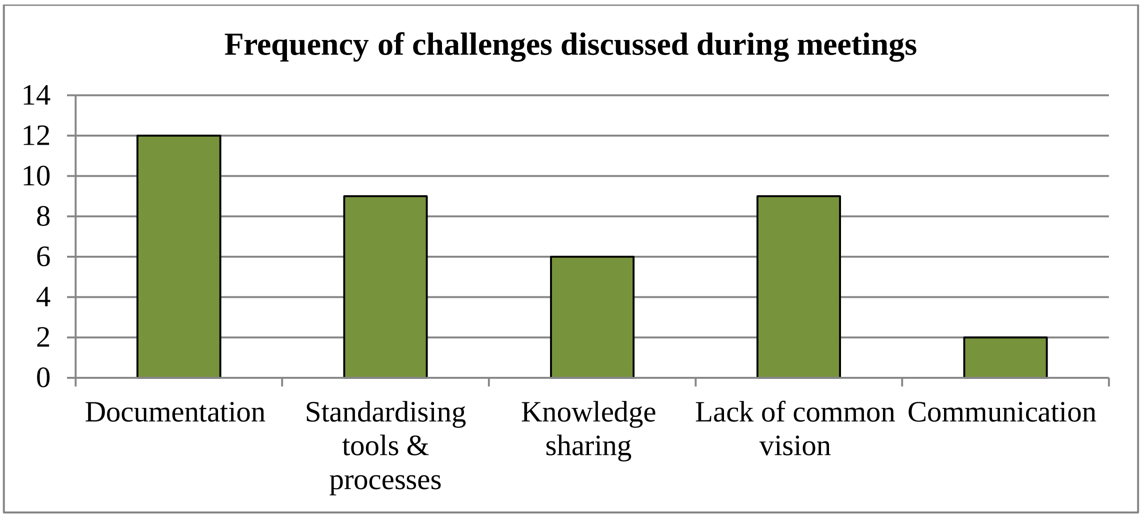

Figure 2Frequency of challenges discussed during project meetings

When considering the research questions for this paper, the most interesting challenge discussed focused on the *Lack of common vision* between the Indian and Danish team. During several meetings, a detailed root cause analysis conducted by the Indian engineers was presented, which resulted in numerous potential solutions to the initial problem. Some of the solutions were considered to be ambitious by the main Danish responsible when considering the KPI communicated at the beginning of the project. The main Danish responsible reminded the Indian team of the KPI and lowered the ambition levels accordingly. Despite this, the Indian engineers continued to propose ambitious solutions during later meetings that would have a positive impact on additional product ranges at the company and hence, increase the value of the “PILOT” project. The Indian team were interested in increasing the value of the project, while the Danish team were interested in working efficiently towards improving the initial problem with the product. The lack of common vision during the project represents a case where coherence between strategic level objectives in GPD and KPIs was lacking. Based on the authors’ experience of the Danish and Indian collaborations, an explanation for this was the Indian engineers were aware the project was a “PILOT” project and therefore, applied additional resources than was necessary for the project in order to prove their value. The *amount of added value* of the project was used as a KPI to measure the performance of the project from the Indian engineering team, which conflicted with the KPI communicated for the project by the Danish main responsible. The misalignment caused increased time to be spent on proposing solutions for the project in India, which had a negative effect on the *Amount of consumed resources.* A further observation when considering the classification of the KPIs, the KPI *Amount of consumed resources* selected for the project is considered a Lagging indicator (Kaplan and Norton, 1992) or a Result indicator (Parmenter, 2010) and a KPI to prevent a situation from occurring during the GPD project was lacking. With this in mind, the authors describe the classification of KPIs with an input-output model, built upon three classification categories (Figure 3):

- Preventive KPI (Input) – set up to prevent a situation from occurring.
- Monitoring KPI (Process) – set up to monitor the progress of what is occurring.
- Outcome KPI (Output) – set up to measure what occurred.

Finally, a reflection process allows for any learning’s to be carried over to future projects.

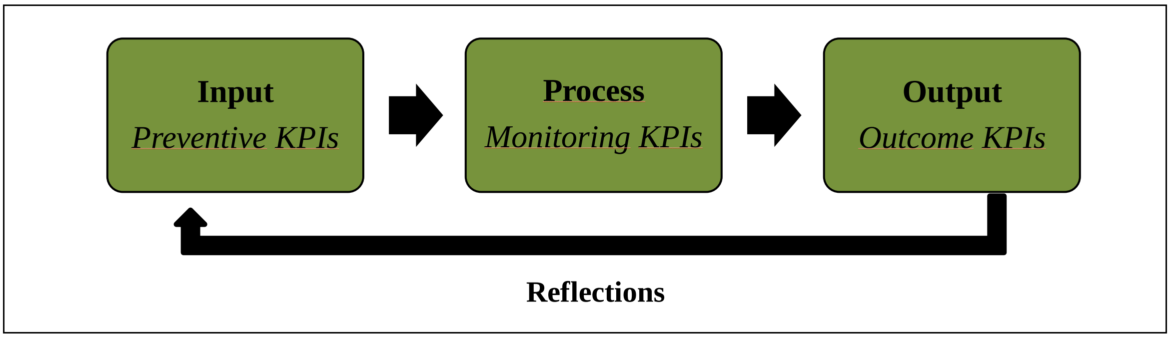

Figure 3 – Classification of Key Performance Indicators in Global Product Development

When considering case previously outlined, the KPI set at the beginning of the project by the Danish engineer: *Amount of consumed resources* is an Outcome KPI. A preventive KPI would focus on minimising the risk of the Indian team attempting to add value to the project, and a process KPI would be set to monitor the number of solutions continually proposed. In this context, the preventive KPI encourages project management to select KPIs based on the challenges and risks bought by globalising PD.

The model represents a method to classify KPIs, which should be understood by practitioners before the selection and implementation of KPIs. Furthermore, the proposed model can be used by researchers in future studies as a method for classifying KPIs.

Conclusion

With the review of literature and resulting empirical studies, this paper investigated the coherence between KPIs selected by management with the strategic level motivations and challenges in GPD. Furthermore, the method for classification of KPIs in GPD was investigated. The review of literature highlighted a lack of research on KPIs for GPD at an operational level. The survey and supplementary exercise presented KPIs related to strategic level motivations and challenges in GPD. A lack of measurable KPIs related to the challenges in GPD meant the coherence could not be investigated. The observations that followed provided a deeper understanding towards the coherence of strategic level objectives with operational KPIs. Results from the empirical studies show that despite practitioners being aware of the challenges in GPD, there is a lack of understanding towards which KPIs should be selected to monitor the risks bought by the challenges. There is a requirement for an alternative approach to performance measurement in GPD to those suggested in literature, which considers the challenges and risks bought by GPD. A KPI classification model was proposed to support practitioners and researchers when classifying KPIs in GPD in future work and studies.

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Appendix 5.4 Paper IV

Status: Submitted to the journal of Production Planning & Control.

Authors	Taylor, T. P., Ahmed-Kristensen, S.
Title	Global product development projects: Measuring performance and monitoring the risks
Submitted to	Production Planning & Control, Taylor & Francis Online, ISSN: 1366-5871.
Research aim	Goal-oriented approaches, traditionally found in conventional PD, do not provide sufficient basis to select KPIs that monitor the key challenges in GPD. There is a need to understand the current approach for the selection of KPIs at the project-level and how the KPIs monitor success to serve as the basis for the development of a support method that supports the selection of KPIs in GPD.
Research stage	Design Research Methodology: Descriptive study I → Prescriptive study
Research approach	Two surveys were conducted: the first with 28 companies; and the second with 16 companies and a longitudinal case study (Company A) to collect information regarding the process for selecting KPIs in GPD projects.
Summary of findings	A structured approach for selecting KPIs during the observed GPD project was not followed. The majority of KPIs selected were based on high level performance dimensions traditionally used in conventional PD: time, cost and quality, which provided a time-delayed, retrospective look on performance and were Lagging in nature. The lagging KPIs were inadequate to avoid challenges in relation to a lack of common vision and misalignment of procedures, which were key causes for project time delays. There was a lack of leading KPIs selected during the project, which identified the factors influencing success along the process.
Contribution	The paper contributes to the thesis by highlighting the importance of selecting leading KPIs in GPD projects and provides guidelines for management that aim to guide with the development of a support method that supports project management with the selection of leading and lagging KPIs in GPD projects.

Global product development projects: Measuring performance and monitoring the risks

The migration from local, cross-functional product development to a form of globally distributed product development (GPD) results in the management of product development projects with globally dispersed engineering teams. The measurement of performance and management of risks in such projects is a challenging yet important step to support this process. However, the relationship between performance measurement and risk management is often overlooked, particularly in the context of GPD at the project-level. This paper investigates the key motivations and risks encountered in GPD projects and how key performance indicators selected at the project-level measure and monitor these. To address this, two surveys with 45 Danish manufacturing companies were conducted, followed by an in-depth longitudinal study with a large Danish manufacturing company. The findings highlight that lagging key performance indicators traditionally used in conventional product development do not provide the necessary feedback required to avoid the risks encountered in GPD projects in relation to a lack of common vision and adherence to a standard product development process. Adopting a risk-oriented approach, rather than purely a goal-oriented approach, to encourage the selection of leading key performance indicators is important in GPD projects to minimise the risks that influence success along the process.

Keywords: global product development; performance measurement; risk management; key performance indicators.

1. Introduction

The opportunity to reduce development costs, gain access to new competencies and expertise or to be closer to the global market has resulted in companies migrating from collocated, cross-functional product development to a form of globally distributed product development (GPD). Managing product development with globally dispersed engineering teams is challenging and issues related to team proximity, cultural differences and difficulties with establishing a common vision have been found to influence the success of GPD at the project-level (Hansen and Ahmed-Kristensen 2011; Siebdrat et al. 2012). Despite this, recent studies illustrate how companies implement strategies to managing these risks on an ad-hoc basis and hence, adopt a learn-by-doing approach to GPD (Hansen and Ahmed-Kristensen 2011; Kitcher 2013). To support the early identification of risks and increase the likelihood of success in GPD, the selection of key performance indicators (KPIs) that monitor both positive and negative influences on success and hence, provide feedback on performance to support decision making is recommended (Christodoulou et al. 2007; Hansen and Ahmed-Kristensen 2012).

The selection of KPIs for the design of performance measurement systems has received much attention in the operations management field, for example Neely et al. (2000) and Folan and Browne (2005) developed comprehensive frameworks for selecting and implementing KPIs at the business-level. However, research on performance measurement in product development at the project-level remains relatively undeveloped, particularly when parts of product development are globally distributed (MacKerron et al. 2015; Taylor and Ahmed-Kristensen 2014). O'Donnell and Duffy (2002) and Tatikonda (2007) highlight how current approaches to performance measurement in product development are goal-oriented and do not consider the risks that influence its success along the process. Given the additional risks involved when globally distributing parts of the product development process, goal-oriented approaches to measuring performance traditionally found in product development may be inadequate to provide the necessary decision support along the process to ensure the success of GPD projects.

This paper contributes to the further understanding of the key motivations and risks encountered in GPD and how key performance indicators used at the project-level measure and monitor these. In doing so, we highlight the importance of adopting a risk-oriented approach to selecting leading KPIs in GPD projects to provide the necessary feedback to support the implementation of precautionary strategies along the process. The paper begins by reviewing the literature in two domains, namely: global product development and performance measurement, highlighting the main gaps in the work to date. The research approach is described and results from two exploratory surveys including 45 participants and an eight-month longitudinal case study with a large Danish manufacturing company are presented. The key implications for both academic and industrial communities are discussed.

2. Literature review

The theoretical underpinning of this paper draws on two fields of study, namely: engineering design, where key motivations and risks related to globalising parts of product development are reviewed and; operations management, where the focus turns to performance measurement for business processes in general with a focus on the selection and use of KPIs.

2.1 Global product development: the key motivations and risks

For a company to conceive, design and commercialise a product, a product development process comprising a sequence of stages is often employed, from the early planning through to final testing and refinement before production ramp up (Figure 1). To remain competitive, many western companies have begun to globally distribute parts of this process, typically starting at the back of the process; beginning with production and moving to development stages, with low value adding activities being outsourced and high value adding activities being offshored (Hansen and Ahmed-Kristensen 2011).

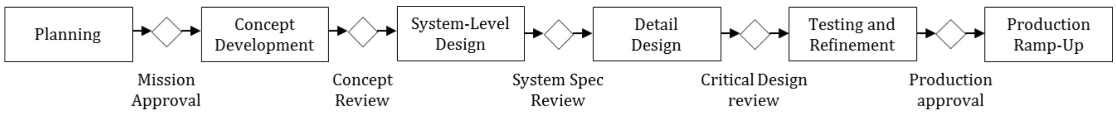

Figure 1 The generic product development process (Ulrich and Eppinger 2011).

Table 1 illustrates the key motivations for GPD from several case studies conducted within the manufacturing sector. Reducing costs, by gaining access to low-cost labour and materials in regions such as Asia and Eastern Europe, is frequently referred to as a key motivation for pursuing GPD. However, studies found that companies pursue GPD for reasons other than those directly related to cost reductions and less tangible benefits may include increased access to technical expertise which is distributed globally, increased flexibility in operations or the sharing and mitigation of product development risk (BusinessWeek Research Services 2006).

Table 1 Key motivations for GPD from several sources in literature.

Authors	**Motivation**	**Example**
Christodoulou et al. (2007)	Cost reductions	Access to low labour costs and materials in low cost regions.
Taylor and Ahmed-Kristensen (2013)	Access to new resources	Increased access to global competencies and engineering expertise.
Hansen and Ahmed-Kristensen (2012)	Increase customer base	Design resources closer to local markets, providing increased knowledge of customer needs.
Eppinger and Chitkara (2009)	Flexibility and scalability	Transferability of tasks and opportunity to work around the clock.
Hansen and Ahmed-Kristensen (2012)	Reduce time to market	Close to local suppliers and global markets.
Verdecho (2009)	Risk mitigation	Sharing risk during development of new products with global partners.

Despite such benefits, it is established in literature that managing product development with globally dispersed engineering teams is challenging and involves a number of risks that can influence the fulfilment of objectives made at the outset (Eppinger and Chitkara 2009; Hansen and Ahmed-Kristensen 2011). In this paper, we consider a risk to be an event having a negative influence on the outcome of a project (Browning et al. 2002). Table 2 illustrates key risks identified that influence the success of GPD during several case studies conducted in the manufacturing sector. The risks are interrelated and often emerge from a companies' versatility towards integrating GPD as a corporate practice and develop processes and procedures suitable for managing globally distributed teams. For example, Hansen and Ahmed-Kristensen (2011) observed that companies tended to continue to operate in the same way as prior to globalising parts of product development in relation to their organisational structures and processes and procedures. The lack of embeddedness towards the product development process at the global R&D site in particular resulted in risks at the project-level such as cultural misunderstandings in the GPD team, design rework and project time delays. Solutions to these risks were implemented on an 'as-needed' basis and dealt with as they arose by the companies without an understanding of the consequences prior to embarking on GPD. Furthermore, during their study Kalyandurg and Akhilesh (2012) highlight that a lack of face-to-face interaction between culturally diverse team members made for a challenging environment when identifying and managing conflicts and creating a common vision within globally distributed teams. They conclude that proactively understanding the risks of working as a part of the GPD team and developing continuous strategies to address such issues is important. Adopting a learn-by-doing approach to GPD without a clear understanding of the potential risks involved can be costly further down the process of product development.

Table 2 Key risks in GPD from several sources in literature.

Authors	Risks	Example
Hansen and Ahmed-Kristensen (2011)	Cultural differences	Contrasting levels of autonomy in project team due to cultural background.
Mcdonough et al. (1999)	Difficulties with communication	Conflicting communication styles: high context and low context.
Crabtree et al. (1997)	Difficulties with documentation	Transfer of company documentation to digital platform accessible to global partners.
Kalyandurg and Akhilesh (2012)	Lack of common vision	Strategic vision created locally at headquarters rather than with global partners.
BusinessWeek Research Services (2006)	Protection of Intellectual property rights	Ideas and inventions can be compromised when shared with parties outside of the company.
Carmel et al. (2009)	Lack of knowledge sharing	Transferring local, tacit knowledge to global partners.
Tripathy and Eppinger (2011)	Standardisation of tools and processes	Clarity of company processes in common language accessible to global partners.

To better manage the risks and support managers in overcoming challenges faced by companies when adopting GPD, Hansen and Ahmed-Kristensen (2012) developed a Global Decision Making framework consisting of the following five stages: (1) Strategic goal setting; (2) Strategic planning; (3) Operational planning; (4) Implementation phases and; (5) Evaluation. Central to operationalising this framework is the development of KPIs that provide continuous feedback to management, in relation to both the positive and negative influences on GPD success, and support decision making along the process. The inclusion of such KPIs that support the identification of deviations early in the process is further supported in literature to better manage GPD projects (Cánez et al. 2000; Christodoulou et al. 2007). Despite this, there is a lack of studies that investigate the design and use of KPIs in the context of GPD. To investigate this, the following section draws on key aspects from the operations management field that focus on the selection and use of KPIs.

2.3 Performance measurement: The selection of key performance indicators

Performance is defined as the effectiveness and efficiency of a process with the purpose of achieving a fixed objective or set of goals (Kaplan and Norton 1996; Neely et al. 2000). The measurement of performance requires a performance measurement system, with the critical element being a balanced set of financial and non-financial KPIs (Ford and Sterman 2003), which in this paper are defined as: quantifiable metrics that help an organisation measure the success of critical factors (Gries and Restrepo 2011). During their development of the Balanced Scorecard, Kaplan and Norton (1996) classify KPIs within two categories:

- Leading indicators: that measure factors influencing a process and are drivers of performance.
- Lagging indicators: that measure output of past activity and typically consist of financial indicators.

The two types of indicators are inter-related and the relationship between the two must be understood. Lagging indicators (outcome measures) without leading indicators (performance drivers) do not communicate how the outcomes of a process are to be achieved. For example, Kaplan and Norton (1996) describe the indicators selected by Metro bank where the company's high level strategy was to achieve revenue growth.

To achieve this, one of the strategic objectives was to create innovative products. The lagging indicator they selected to measure the outcome of this objective was the 'Amount of revenue from new products'. The leading indicator they selected to 'drive' performance towards achieving this objective was to monitor the 'Amount of hours spent with the customer'. In this case, the leading indicator was driving performance towards creating innovative products by spending time with the customer, whereas the lagging indicator was measuring the financial implications at the end of the process.

A general criticism towards KPIs in product development is they are predominantly lagging in nature and provide a time delayed, retrospective look on performance (Driva 1997; Tatikonda 2007), rather than an instantaneous evaluation or predictive insight along the process, which can otherwise be achieved when using leading KPIs. Furthermore, O'Donnell and Duffy (2002) highlight that existing approaches to performance measurement in product development almost exclusively focus on the performance of the design artefact (the outcome) and not the performance of the activities required for its development (the process). For example, they do not consider the trade-off between the cost of the product development process and the quality of the final product.

The importance of selecting KPIs that monitor factors influencing the success of a process, rather than solely KPIs that measure past performance, has been highlighted in the operations management field (Franco-Santos and Bourne 2005; Neely et al. 2000; Medibil and MacBryde 2007). As part of their work on performance measurement system design, Neely et al. (2000) proposed six desirable characteristics for designing KPIs: (1) Indicators should be derived from the company's strategy; (2) The purpose of the indicator must be made explicit; (3) Data collection and methods of calculating performance must be clear; (4) All stakeholders must be involved in the selection of the indicators; (5) The indicator should take account of the organisation and; (6) The indicators should change as circumstances change. Building on these recommendations, Folan and Browne (2005) propose a framework which provides a step-by-step generic process for the selection of KPIs in extended enterprises. A critical element of the framework is the early identification of critical success factors for the business as an approach for selecting purposeful KPIs. However, in the dynamic and often unpredictable environment that characterises product development at the project-level, the practicality of frameworks for selecting KPIs that focus at the business-level has been criticised (Molleman 2007; O'Donnel and Duffy 2005). At the project-level, Mendibil and Macbryde (2007) developed a framework that aims to support the development of KPIs that focus on team-based performance measurement, which encourages the selection of KPIs according to key drivers of team performance. Their frameworks offer guidance towards the selection of KPIs to measure performance. However, it is difficult to understand if such frameworks are applicable within the context of GPD at the project-level given the additional risks and motivations and the requirement for KPIs that monitor both positive and negative influences on success.

2.4 Summary and research questions

There is a lack of research that focuses on the selection and use of KPIs in GPD despite the importance of including such indicators to monitor both the positive and negative influences on success and support decision making. Additional risks that influence the success of GPD at the project-level require monitoring to ensure that deviations can be identified early to support the implementation of preventative strategies. However, current frameworks that support the selection of KPIs primarily focus at the business-level and do not incorporate a risk-oriented approach to measurement. As such the research sought to answer the following questions:

(1) How do key motivations and risks in global product development projects influence the key performance indicators selected that measure performance?
(2) What is the process for selecting key performance indicators at the project-level and how do these monitor the key risks in global product development?

The research approach to investigate the research questions is described in the following section.

3. Methodology

The section describes the research aim and approach, the method for data collection followed by the method for data analysis.

3.1 Research aim and approach

The main aim of the research study was to develop an understanding toward the key motivations and risks encountered in GPD and how key performance indicators used at the project-level measure and monitor these. To address the aim, two empirical studies were conducted with the first study influencing the direction of the subsequent study. A combination of research methods were adapted for the studies as multiple sources of evidence increase the reliability of data (Yin 2009). The studies included:

(1) An exploratory study - two cross-company surveys were conducted with a broad range of Danish manufacturing companies and provided an initial understanding towards key motivations, risks and KPIs in GPD projects. Survey I was conducted online and included 28 participants from 28 companies and Survey II was a paper-based survey including 17 participants from 16 companies. Surveys were deemed appropriate at this stage as they are useful for collecting information where no data, or insufficient data, exist (Statistics Canada 2010).

(2) An eight-month longitudinal case study – 12 interviews, 27 observations during project meetings and the analysis of company documentation were conducted at a large Danish manufacturing company in Denmark and provided an in-depth understanding towards how key performance indicators monitor and measure key risks encountered in GPD projects. A case study was considered appropriate at this stage as case studies provide an in-depth understanding of a variety of contextual factors, which may be too complex to gain understanding with a survey for example (Yin 2009).

3.2 Data collection

3.2.1 The exploratory study

Survey I was distributed via email to 100 companies in Denmark characterised by their high involvement with GPD (see Table 3 for participants of Survey I). To minimise the response error, a pilot survey was sent to a smaller sample of respondents that were both internal and external from the research project to identify any difficulties with the questions. This resulted in minor adjustments to the user-interface before the final survey was distributed. The survey was kept short, approx. 10 minutes, to increase the response potential. First, participants were asked to state the motivations for GPD and second, to select KPIs used for measuring progress towards these motivations. It was of interest to capture the motivations for GPD given the importance highlighted in literature of selecting KPIs according to strategic objectives (Neely et al. 2000). Open-ended questions were used for investigating the motivations and multiple choice questions for the KPIs. The possible answers to the multiple choice questions were structured related to the most common KPIs for conventional product development (Griffin and Page 1996) as a comprehensive set of KPIs for GPD could not be identified at the time of research. An ‘other’ checkbox provided participants with the opportunity to include KPIs specific to GPD.

Survey II was a paper-based survey conducted during an industrial workshop focussing on performance measurement in GPD with a previously established interest group, characterised by their high involvement with GPD (see Table 3 for participants of Survey II). The survey was kept short, approx. 10 minutes, and the researcher assisted the respondents in completing the survey when necessary. This helped to minimise the response errors and maximise the response potential. The design of Survey II was kept as similar as possible to Survey I to allow for the comparison of results. However, in addition to stating the motivations for GPD and KPIs for measuring these, participants in Survey II were asked to state the risks they encountered in GPD projects and the KPIs used for monitoring these. It was of interest to capture the risks given the importance expressed in literature of selecting KPIs that monitor both positive and negative influences on success (Hansen and Ahmed-Kristensen 2012). Multiple choice questions for capturing the motivations and risks were used in Survey II with answers to these based on the key motivations and risks identified in Survey I and in the literature (Table 1 and Table 2). Open-ended questions were used when asking participants to state the KPIs used for measuring and monitoring their previously stated risks and motivations.

Table 3 Participants of Survey I and Survey II from the exploratory study.

Participant characteristics:		**Number of participants for Survey I**	**Number of participants for Survey II**
Size:	Small (<50)	7	6
	Medium (50-250)	2	5
	Large (>250)	19	6

Industry sector:	Manufacturing	17	14
	product development	9	2
	Electronics	2	1
Position:	Senior management	14	6
	Middle management	14	11
Total number of participants:		**28**	**17**

3.2.2 The case study

The case study was conducted with a large Danish manufacturing company, which was selected from the participants during the exploratory study of this research, and focussed on the collaborations between a local R&D site in Denmark and an offshored R&D site in India. A description of the company and background of the collaboration between the Danish and Indian R&D sites is presented in the following paragraph and a description of the methods for data collection follows this.

The company specialise in the production of industrial valves and controls for the refrigeration and air conditioning markets. In 2011, the company established an offshore R&D department in India with the key motivation to reduce costs by gaining access to low labour costs of skilled engineers in India. At the beginning of the collaboration, the Indian R&D were invited to the headquarters in Denmark for a three month training program, which focussed on familiarising the Indian engineers with standard processes and procedures at the company. However, since the collaboration began the Danish engineers experienced difficulties with the Indian engineers and a number of tasks and activities were neither completed on time nor to the desired quality. The motivation of the Indian engineers towards the tasks, which were routine in nature, was seen as a contributing factor to these difficulties and therefore a lead engineer in Denmark decided to involve the Indian engineers as the ‘main drivers’ in a more complex product development project in order to increase their motivation. The completion of this GPD project, from the early planning through to the final testing of the product, forms the basis for the results reported in this paper for the case study. The objective of the project was to improve the performance of an existing valve range by increasing the product lifetime. The project was introduced as a 'Pilot' project and the solution was known by the Danish engineers with the primary aim to improve the collaborations, whilst keeping risk low. The project was expected to last three to four months and followed the standard product development process at the company (Figure 2), which was comparable to the generic product development process highlighted in literature (Figure 1). The project involved 10 experienced mechanical engineers from the R&D sites in India and Denmark (See Table 4 for characteristics of the GPD project investigated).

Figure 2 Standard product development process followed at the company case study.

Table 4 Characteristics of GPD project investigated at the company case study.

Project characteristics	
Product to be developed	Industrial valve
Expected duration of project	3-4 months
Product development phases investigated*	P1, P2, P3, P4, P5
Offshored R&D site involved in project	India
No. of years offshored R&D established at time of study	2.5

Note: *Refer to Figure 2 for product development project phases

To strengthen the results of case study research and to fully investigate the research aim, multiple methods of data collection were carried out during the case study, allowing for the triangulation of results (Eisenhardt 1989). The characteristics of the data collection methods and participants are summarised in Table 5. In addition to the observations and interviews, company and project documentation such as detailed project plans, risk assessments, key project metrics and meeting minutes that formed part of the routine tasks at the company were collected and organised to highlight facts and events to further support the aims of the study. The two main sources of data are described further here.

- The 27 observations made during project meetings provided the in-depth understanding to investigate the sequential relationship of events and hence, enabled an understanding towards how selected KPIs monitored and measured the key risks encountered during the observed GPD project. The observations were conducted over a time period of eight months and focused on the GPD project described previously. The researcher did not participate during the observations. 10 mechanical engineers from the Indian and Danish R&D department were observed during the GPD project and the meetings were conducted during an online video conference. It was not possible to record all observations made during the project and therefore detailed field notes were kept and organised according to the aims of the research study, which is discussed in more detail in the following section.
- The interviews were used as a secondary data source and provided an understanding toward the Danish and Indian R&D collaboration retrospectively. Semi-structured interviews were conducted and an interview guide was developed based on the aims of the research study. First, the interviewees were asked to describe how the collaboration with the team in India had affected the team in Denmark (and vice versa) and second, they were asked to describe the

current practice for measuring performance in GPD projects. The 10 mechanical engineers, who formed the core team that participated during the observations of the GPD project, were also selected as participants for the interviews given their experience with the GPD project under investigation. In addition, 2 top-level managers from the R&D in Denmark were interviewed given their experience with the collaboration in general. The interviews were audio-recorded and transcribed to allow for further analysis.

Table 5 Characteristics of the data collection methods and participants in the case study.

Characteristics:	**Observations**	**Interviews**
No. of participants	6 x Danish, 4 x Indian engineers	8 x Danish, 4 x Indian engineers
No. of observations	27 project meetings	n/a
Length	30-90 minutes	60 minutes
Type	Non-participative	Semi-structured
Location	Online video conferences	3 x face-to-face, 9 x telephone
Time period of observations	8 months	n/a

3.3. Data analysis

A coding scheme for categorising the data was developed and redefined as the research study progressed, which was based on the ongoing analysis and reflection of data collected during the two studies and key themes that emerged from the literature review. As a result of the exploratory study, three main themes were developed in the coding scheme including: (1) key motivations for GPD; (2) key risks for GPD and; (3) KPIs for measuring and monitoring key challenges and motivations. Data collected during the exploratory study, i.e. the results from Survey I and Survey II, and the case study, i.e. the transcriptions from the interviews and the field notes from the observations, were grouped according to the main themes. Following this, the data were categorised within these themes according to a more specific set of codes. The codes were developed based on the literature review and also key patterns emerging from the empirical studies; so as to avoid the confinement of data, i.e. the predefined coding scheme allowed for bottom up categories if the top down categories from literature were insufficient. For example, research toward key motivations and risks for GPD is maturing and therefore, many of the codes within these two main themes could be developed based on the key motivations and risks identified in the literature review (Table 1 and Table 2). However, research towards performance measurement in GPD is relatively underdeveloped and therefore, a number of codes for the stated KPIs were generated based on the empirical data. Furthermore, additional sub-codes to those created during the exploratory study were developed given the in-depth understanding provided by the case study. For example, during the case study it was possible to categorise KPIs according to whether they were 'leading KPIs' or 'lagging KPIs'. The categorisation of data was an iterative process with new categories being developed as the study progressed. Table 6 illustrates an example of some of the codes developed according to the main themes in the coding scheme. A coder-reliability check was conducted for the final coding scheme (Cohen 1962), where two researchers categorised parts of the data from the exploratory study and case study within the developed coding scheme. The coder-reliability check indicated a strong validation coefficient, i.e. the categorisation of the data was not subjective. Furthermore, if the same activity, and therefore the same code, were observed in more than one study, the coding scheme was assumed to be valid. Following this, frequency counts of the coded data indicated the key relationships and patterns that emerged during the two studies. Following the frequency counts, the qualitative analysis of the patterns indicated provided an understanding of the rationale and theory underlying relationships. The analysis of the coded data is comparable to approaches adopted by Eisenhardt (1989) and Braun and Clarke (2006) where qualitative data is supplemented by frequency counts of code occurrence.

Table 6 Excerpt from the coding scheme used for data analysis.

Main theme	**Code**	**Example**
Motivation for GPD	Cost reductions	Access to low labour costs and materials in low cost regions.
	Access to new resources	Increased access to global competencies and engineering expertise.
Risk in GPD	Lack of knowledge sharing	Difficulties with transferring local, tacit knowledge to global partners.
	A lack of common vision	Difficulties with managing expectations in GPD team.
KPI used	Documentation errors	Number of errors found in drawings completed.
	Project lead time	Amount of time from project initiation to completion.

4. Findings

The key findings from the exploratory study and case study are presented in the following section.

4.1 The exploratory study

4.1.1 KPIs for measuring the key motivations for GPD

Table 7 illustrates the KPIs relative to the motivations for GPD, stated by the respondents from Survey I and Survey II. The frequency the motivations and KPIs were stated is also illustrated. The motivations for GPD were categorised according to those highlighted in literature (Table 1) without the requirement for additional categories. *Cost reductions* was the most frequently stated motivation with a count of 24, suggesting that the opportunity to reduce costs was a common motivation for GPD.

These findings are consistent with previous studies that investigate the motivations for pursuing GPD (BusinessWeek Research Services 2006). A total of 21 KPIs were stated for measuring the motivations, 12 of which could be categorised according to common KPIs found in conventional product development (Griffin and Page 1996) and 4 KPIs that could not be categorised and were stated as 'other' KPIs by respondents. This implies that additional KPIs to those commonly found in conventional product development are required for measuring the motivations for GPD. *Development cost*, *Project lead-time* and *Customer satisfaction* were the most frequently stated KPIs for measuring the motivations, which are also common KPIs used in conventional product development (Griffin and Page 1996). The majority of the 'other' KPIs stated focus on measuring the outcome as a result of pursuing GPD such as the *No. of sales from new location, No. of new alliances* and *No. of solved work packages.* Alternatively, the *Capability of supplier delivery* evaluates the potential for success before pursuing GPD in relation to the capability of the supplier to perform as expected. The majority of the KPIs focussed on measuring *Cost reductions,* which is consistent with the high frequency it was stated. This implies that respondents found it easier to state KPIs related to quantifiable, financial outcomes i.e. *Development cost*, *Return-on-investment, Profit goals met, Margin goals met,* etc.

Table 7 KPIs for measuring key motivations in GPD: Survey I and Survey II.

Motivations for GPD	**Freq.**	**KPIs**	**Freq.**
Access to new resources	17	Leads to future operations	3
		Percentage of new product sales	2
		No. of new projects	2
		No. of new alliances*	2
Cost reductions	24	Break-even time	3
		Return on Investment	6

		Margin goals met	5
		Development cost	15
		Profit goals met	3
Reduce time to market	11	Project lead time	14
		Project plan status	8
Flexibility and scalability	16	Capability of supplier delivery*	2
		Market position	5
Increase customer base	5	Customer satisfaction	10
		Market share	5
		No. of sales from new location*	1
Risk mitigation	3	No. of solved work packages*	1

Note: *'Other' KPIs stated that could not be categorised according to common KPIs in conventional product development.

4.1.2 KPIs for monitoring the key risks in GPD

Table 8 illustrates the KPIs for monitoring the risks encountered in GPD, stated by the respondents from Survey II. The risks were categorised according to those highlighted in literature (Table 2) without the requirement for additional categories. *Communication difficulties* and *Cultural differences* were the most frequently stated risks encountered in GPD, with counts of 16 and 10 respectively, which have also been found to be important risks in previous studies investigating GPD (Hansen and Ahmed-Kristensen 2011). A total of 8 KPIs were stated for monitoring the risks in GPD, 2 of which could be categorised according to common KPIs in conventional product development (Griffin, Abbie, Page, 1996) and 6 'other' KPIs that could not be categorised. The KPIs were only stated once, with the exception of *Frequency of process problems*, which was stated twice. The majority of 'other' KPIs stated focus on the occurrence of problems encountered during GPD projects in relation to communication, documentation and general process/ project issues. In comparison to 'other' KPIs stated for measuring the motivations, which focus on measuring the outcome as a result of pursuing GPD, the 'other' KPIs stated for monitoring the risks monitor factors that influence the success of the outcome along the process such as *No. of problems during project, Frequency of communication problems, Frequency of process problems.* Despite the lower number of KPIs stated for monitoring the key risks in comparison to the key motivations, a large number of answers were provided by respondents when asked to state KPIs for monitoring the previously stated risks for GPD. However, during the categorisation process (see section 3.3) and based on the desirable characteristics of KPIs recommended by Neely et al. (2000), many of these answers were not considered to be KPIs and were not included in Table 8. For example, *Understanding of the situation* was stated as a KPI for monitoring the risk of *Cultural differences* and *Gut feeling* as a KPI for monitoring *Communication difficulties.* The broad variety of answers and lack of measurable KPIs suggests that participants experienced difficulties when stating KPIs for monitoring the risks in GPD. An explanation for this may be given the difficulty in selecting KPIs for monitoring intangible factors, such as the risks in GPD. In the context of product development, it was found that management often select KPIs that measure an outcome of a process and tend to focus on more tangible aspects (Tatikonda 2007). However, the high frequency that risks such as *Communication difficulties* and *Cultural differences* were stated reflects their importance in the context of GPD and monitoring the influence that these risks have on success is important and is further confirmed in literature (Christodoulou et al. 2007; Hansen and Ahmed-Kristensen 2012).

Table 8 KPIs for monitoring key risks in GPD: Survey II.

Risks in GPD	**Freq.**	**KPIs**
Communication	16	No. of project goals met on time

		No. of agreements kept*
		No. of problems during project*
		Frequency of communication problems*
Cultural differences	10	Employee feedback on job stability*
IP rights	5	No. of patents
Knowledge sharing	7	Availability of documentation*
Standardising tools and processes	5	Frequency of process problems*

Note: *'Other' KPIs stated that could not be categorised according to common KPIs in conventional product development.

The results from the exploratory survey provided initial understanding towards how the key motivations and risks encountered in GPD projects influence the selection of KPIs, addressing the first research question in this paper. Building on these results, a case study was conducted to provide the in-depth understanding required to investigate the process for selecting KPIs and how KPIs monitor and measure key risks encountered in GPD at the project-level. Results from the case study are presented in the following section.

4.2 The case study

4.2.1 KPIs for monitoring the key risks during the observed GPD project

Table 9 illustrates the KPIs used for monitoring the risks encountered in the GPD project investigated at the case company. The frequency that the risks and KPIs were discussed during the observed project meetings is highlighted. The KPIs are classified according to whether they were leading i.e. monitored factors influencing a process and were drivers of performance, or lagging i.e. measured the output of past activity. The project phase that the risks were discussed and the KPIs used is illustrated. The key findings from Table 9 are summarised here and the implications of these are discussed together with the relevant literature in more detail in the following section.

- *A lack of common vision* within the project team was the most frequently discussed risk during the planning and detail design phase of the project, which was discussed on 14 separate occasions.
- The lack of adherence to the *Standardised tools and processes* was the second most frequently discussed risk during the project clarification phase of the project with a count of 6.
- The majority of the KPIs were used as lagging KPIs and focussed on measuring the outcome of past activity. Only 2 KPIs were used as leading KPIs to monitor the factors that influenced the success of the project along the process.

Table 9 KPIs for monitoring the risks at the company case during the investigated GPD project.

Risks	**Freq.**	**KPIs**	**Freq.**	**KPI classification**	**Project phase***
Lack of knowledge sharing	3	Planned resources Vs Actual resources	1	Lagging	P1 - P2
Lack of common vision	14	Internal design expert feedback	3	Lagging	P4
		Expected Vs. Actual completion date	6	Lagging	P1 - P2
		Alignment of concept propositions with design specifications	3	Lagging	P1 - P2
		No. of deliverables met	5	Lagging	P1 - P2
Insufficient resources**	2	Project lead time	3	Lagging	P1-P5
		Return on investment	2	Leading	P1 - P2
Product failure**	2	Supplier feedback on assembly	1	Leading	P4

		Proposed concept Vs Product specifications	1	Lagging	P4
Standardising tools and processes	6	No KPIs were used for monitoring this risk			P1 - P2

Note: *Refer to Figure 2 for project phase, **'Other' risks discussed that could not be categorised according to common risks in GPD (Table 2).

4.2.2 The use of lagging KPIs for measuring performance

In the observed GPD project, a structured approach for selecting the KPIs was not followed at the project-level. However, the majority of the KPIs used for measuring the performance of the project, illustrated in Table 9, were based on the standard process followed for product development projects at the company. For example, the product development process involved the calculation of budgetary requirements, project scheduling and predefined product quality requirements for the product, which were in line with the strategic objectives at the company. The KPIs related to these at the project-level, such as *Return on investment, Project lead time, Expected Vs actual completion date,* etc. were measured throughout the completion of the project during the observed project meetings. KPIs that relate to development time, project cost and product quality are also common in product development projects and are important indicators of project success (Ulrich and Eppinger 2011). However, a general criticism of such KPIs in product development is they are lagging in nature and provide time-delayed feedback on performance (Tatikonda 2007). Given the additional risks encountered during the observed GPD project (Table 9), the lagging KPIs used in the project did not provide the predictive insight required to setup intervention strategies to avoid the risks encountered and as a result, the project was delayed by two and a half months. This is further elaborated on in the following section.

4.2.3 The lack of leading KPIs for monitoring the risks

A lack of common vision in the project team and adherence to the *Standardised processes* during the observed GPD project were key causes for the project being delayed by two and a half months. There were a lack of leading KPIs used to monitor these risks and the implications of this are further discussed here.

The GPD project was introduced to the Indian R&D as a ‘Pilot’ project with the aim of improving the collaborations with the Danish R&D. As such, the Indian engineers felt the need to perform to a high standard and invested a large amount of time and resources during the planning phase of the project and proposed a number of solutions, which would potentially add value to the project and impact additional product variants outside of the project. However, these propositions were rejected during a project meeting in the detail design phase of the project as they were considered too ambitious given the solution the Danish R&D had in mind. The project meeting focussed on the evaluation of the proposed solutions against the design specifications to ensure that there was a common vision within the project team in relation to the product to be developed. This involved feedback from a number of design experts from the Danish R&D and hence, the KPI *Internal design expert feedback* was measured. The rejection of the propositions caused confusion amongst the Indian engineers in relation to the project expectations and resulted in design rework, which was a key cause for the project being delayed by two and a half months.

The risk of this lack of common vision within the project team was identified whilst conducting the standard project risk assessment at the company in the planning phase of the project. This involved identifying the root cause of the risk and reporting the likelihood and influence the risk may have on project success. Despite following this process, the influence that a lack of common vision had on the project in terms of time delays was only identified during the later stages of the project when measuring the lagging KPI: *Internal design expert feedback.* A leading KPI, which have been described to measure factors influencing the success of a process and drive performance (Kaplan and Norton 1996), was not selected to monitor the influence of the risk throughout the progression of the project, and hence adjustments were only made once the risk had influenced the success of the project in terms of timing.

A further risk observed during the GPD project, which contributed to the project time delays, was the lack of adherence to the *Standardised processes* at the company during the early stages of the project. To allow the GPD team to work concurrently and support the coordination of tasks between the Danish and Indian R&D engineers, the Danish R&D recommended following the standard process for product development projects at the company (Figure 2). However during the early planning stages of the project, the Indian R&D planned their tasks according to a Six Sigma process as they felt it was complimentary to the standard process recommended by the Danish R&D. As a result, increased time was spent during the early stages of the project as the Six Sigma process resulted in an in-depth root cause analysis conducted by the Indian R&D. The Danish R&D spent time to re-align the tasks completed by the Indian R&D with those recommended in the standard product development process and further contributed to the project time delays. The importance of following a standardised process to support GPD has been highlighted (Eppinger et al. 2009). However, the lack of adherence towards the standard product development process was not identified as a key risk to the success of the project and KPIs were not used to monitor this risk.

In sum, the findings from the exploratory study highlighted the difficulties experienced when selecting KPIs to monitor key risks encountered in GPD projects. To further investigate this, the case study provided the in depth understanding towards how KPIs monitor and measure key risks encountered in GPD at the project-level. The key findings were:

- A lack of common vision and adherence to the standard product development process influenced the success of the observed GPD project and resulted in design rework and project time delays.
- The majority of the KPIs used during the GPD project were lagging in nature and did not provide the predictive insight required to monitor the identified risks and make adjustments along the process to minimise design rework and project time delays.
- Despite identifying the key risks in the early stages of the project during the project risk assessment at the company, leading KPIs, which have been described to measure factors influencing the success of a process and drive performance, were not selected during the project to monitor the risks.

In the case described, the lagging KPIs used did not provide the necessary feedback to management to make adjustments along the process and avoid the risks in the GPD project. Such approaches to measurement have been criticised as lagging KPIs, commonly found in conventional product development, provide a time delayed retrospective look on performance (Tatikonda 2007). Given the additional risks involved with GPD, the need to monitor both positive and negative influences on success has been highlighted (Christodoulou et al. 2007; Hansen and Ahmed-Kristensen 2012).

5. Discussion

5.1 Lagging KPIs for measuring the key motivations in GPD

The first research question in this paper aimed to develop an understanding toward how key motivations and risks in GPD projects influence the KPIs selected to measure performance. Based on the results from the exploratory study, the number of 'other' KPIs stated by respondents, which could not be categorised according to common KPIs found in conventional product development, implies that alternative KPIs for measuring the motivations, and in particular for monitoring the risks, are required in the context of GPD. For measuring the motivations, many of the KPIs traditionally found in conventional product development, such as *Development cost*, *Project lead time* and *Customer satisfaction* are also used to measure the performance of tangible outcomes in GPD such as *Cost reductions*, *Reductions in time to market* and the *Increase in customer base*. In addition, the 'other' KPIs stated focussed on measuring tangible outcomes as a result of pursuing GPD, such as *No. of sales from new location* and *No. of new alliances,* and were predominantly lagging in nature. This is consistent with findings in literature that highlight the tendency of practitioners in product development to select lagging KPIs that measure the more tangible outcomes (Tatikonda 2007). However, such KPIs have been described to provide a retrospective look on performance rather than the instantaneous measurement required to make adjustments along the process. In the context of GPD, the importance of selecting KPIs that monitor the less tangible 'soft' factors that influence success becomes increasingly important (Hansen and Ahmed-Kristensen 2012).

5.2 Leading KPIs for monitoring the key risks in GPD

Participants experienced difficulties in stating KPIs to monitor the less tangible risks in GPD, such as *Cultural differences* and *Communication difficulties,* despite the perceived importance of these risks. This can be expected given the difficulties in developing KPIs to measure less tangible factors. However, KPIs that were stated focussed on factors influencing the success of GPD projects such as *No. of problems* *during project* and *Frequency of communication problems.* This implies that identifying key risks prior to selecting KPIs encourages the selection of KPIs that monitor factors influencing the success of a process and hence, are leading in nature. Leading KPIs focus on the measurement of factors influencing success along the process (Kaplan and Norton 1996) and hence, provide the necessary feedback for management to implement strategies to avoid risks along the process (Scrivener 2003). However, to fully investigate the use of leading and lagging KPIs, a more in-depth understanding of GPD at the project-level was required.

The second research question in this paper aimed to develop an understanding toward the process for selecting KPIs at the project-level and how selected KPIs monitor the key risks encountered in GPD. Results from the case study provided this understanding. *A lack of common vision* and *lack of adherence to the standardised processes* in the GPD team were key risks observed in the GPD project, which negatively influenced the fulfilment of project objectives in relation to the expected project completion date made at the outset. These findings further highlight the importance of proactively understanding the risks of working as a part of a GPD team and developing continuous strategies to address such issues (Kalyandurg and Akhilesh 2012). However, despite identifying *A lack of common vision* as a key risk to the success of the GPD project during a project risk assessment, leading KPIs, described as KPIs that monitor factors influencing a process and are drivers of performance (Kaplan and Norton 1996), were not selected to monitor this risk. Rather, lagging KPIs were used and resulted in a time delayed look on performance, which was inadequate to proactively implement strategies to avoid design rework and project time delays. This resulted in solutions to the risks being implemented on an ‘as-needed’ basis, which can be costly further down the process, and is further exemplified in previous studies where companies adopt a learn by doing approach to GPD (Hansen and Ahmed-Kristensen 2011; Kalyandurg and Akhilesh 2012). This reaffirms the need expressed in literature for KPIs that monitor both positive and negative influences in GPD to provide feedback that supports the implementation of precautionary strategies along the process.

5.3 The need for a structured approach for selecting KPIs

The standard process for product development at the company followed during the GPD project was the primary support for selecting and documenting the KPIs. As a result, many of the KPIs focussed on development time, project cost and product quality, which are also common in product development projects and are important indicators of project success (Ulrich and Eppinger 2011). However, solely selecting KPIs according to these dimensions did not provide sufficient support for selecting leading KPIs to monitor the key risks that eventually influenced the success of the observed GPD project.

Based on the findings from the empirical studies, incorporating a risk-oriented approach to encourage the selection of both leading and lagging KPIs is important for the success of GPD projects. Given the difficulties in selecting KPIs that monitor the less tangible risks in GPD, there is a requirement to support project managers during this process to avoid the selection of KPIs that solely focus on measuring tangible outcomes and are lagging in nature. Key aspects for the selection of KPIs that focus on deriving KPIs from business-level strategy also apply within the context of GPD (Franco-Santos and Bourne 2005; Neely et al. 2000; Medibil and MacBryde 2007). However, building on these frameworks and to support a risk-oriented approach to selecting KPIs at the project-level in GPD, the authors suggest that it is first important to identify and understand the cause-effect relationship between: (1) the key motivations that represent the desirable outcome for the GPD project e.g. *Reduce time to market* and; (2) the key risks that influence success towards this outcome e.g. *A lack of common vision*. Identifying cause-effect relationships to measure the effects of outsourcing in general has also been adopted in previous studies (Kitcher 2013). This understanding could provide the basis for the selection of the following KPIs:

(1) Lagging KPIs, which measure the performance of past activity once the project is complete in relation to the desirable outcomes and motivations for GPD made at the outset e.g. *No. of deliverable met*, and;
(2) Leading KPIs, which monitor the key risks that influence the success towards the desired outcome and hence, provide timely feedback to support the proactive implementation of strategies to avoid risks along the process e.g. *Frequency of communication problems*.

5.4 Implications for industrial and academic communities

The research builds on previous studies that highlight the importance for developing KPIs in relation to both positive and negative influences on success to support decision making in GPD (Cánez et al. 2000; Christodoulou et al. 2007; Hansen and Ahmed-Kristensen 2012). As a result of the empirical studies the following implications for industry are highlighted:

- Proactively understanding risks that influence the success of GPD, such as a lack of common vision and adherence to standard processes, and developing precautionary strategies to address such issues is important.
- A risk-oriented approach to selecting KPIs in GPD should be adopted to encourage the selection of leading KPIs, which provide the required feedback along the process to implement strategies to avoid the risks that influence the success of GPD projects.

For the academic community, in tracing observed problems in GPD back to their initial causes, indications as to where practical tools should be developed to support the management of GPD projects is provided. In general, the empirical studies conducted builds knowledge regarding the global dispersion of engineering design activities in practice, which is seldom addressed with longitudinal observational studies, providing the basis for researchers to develop practical tools to support GPD.

6. Conclusion

This paper highlights the importance of adopting a risk-oriented approach to selecting KPIs in GPD at the project-level to support the implementation of precautionary strategies along the process. The literature review demonstrated that although research has focussed on the selection and use of KPIs at the business-level, there has been little attention towards how KPIs are selected and used in the context of GPD at the project-level i.e. how they should be tailored for a specific project to monitor and measure the factors important for managing globally dispersed engineering teams.

To address this, an exploratory study was conducted, including two cross-company surveys with Danish manufacturing companies, which provided initial understanding towards how key motivations and risks in GPD influenced the selection of KPIs at the project-level. Despite the perceived importance of the risks related to cultural differences and communication difficulties, participants experienced difficulties in stating KPIs to monitor the less tangible risks in GPD. These findings provided data from a number of companies. Based on these findings, results from an eight month longitudinal case study with a large Danish manufacturing company provided a deeper understanding towards the process for selecting KPIs at the project-level and how selected KPIs monitor key risks encountered in GPD. During the observed GPD project, a lack of common vision and a lack of adherence to the standard product development process influenced the success of the project and resulted in design rework and project time delays. However, the KPIs selected that monitored the risks were predominantly lagging in nature and provided time-delayed feedback towards these rather than an instantaneous measurement along the process, which can otherwise be achieved with leading KPIs. As such, a lack of common vision was identified late in the project without the necessary indication of where to implement precautionary strategies to avoid design rework and project time delays.

Based on the findings from the empirical studies and key concepts adopted from GPD and performance measurement (Kaplan and Norton 1996; Mendibil and MacBryde 2007; Hansen and Ahmed-Kristensen 2012), the importance for management to adopt a risk-oriented approach to selecting KPIs in the context of GPD is highlighted to encourage the selection of leading KPIs that drive performance. Leading KPIs, which monitor factors influencing success along the process, can provide the required feedback to implement strategies to avoid risks that influence the success of GPD projects. The paper makes the following contributions by developing an understanding towards:

- The selection and use of KPIs in GPD at the project-level.
- The importance of selecting KPIs in GPD to minimise the risks in addition to KPIs that are purely goal-oriented.

In general, the empirical studies conducted builds knowledge regarding the global dispersion of engineering design activities in practice, which is seldom addressed with longitudinal observational studies, providing the basis for researchers to develop practical tools to support GPD. However, caution should be taken when generalising the findings reported. The results of the empirical studies are derived from the analysis of Danish manufacturing companies who currently globalise parts of their product development activities and hence, it makes sense to state that the findings are valid within this context. Furthermore, case studies conducted in their natural setting makes it difficult to control single factors such as culture or distance that can otherwise be controlled in a laboratory setting. Despite this, case studies carried out in their natural environment provide in depth understanding of real time tasks and activities that lead to creative insights of high validity for practitioners (Voss et al. 2002).

Building on this study, future studies should focus on the development of practical tools that incorporate a risk-oriented approach to the selection of KPIs and hence, result in the selection of KPIs that monitor both the positive and negative factors that influence the success in GPD. Furthermore, there is a requirement for additional longitudinal observational studies that trace observed problems in GPD back to their initial causes and hence, providing indication as to where practical tools should be developed to support the management of GPD projects.

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Appendix 5.5 Paper V

<u>Reference:</u> Taylor, T. P., Ahmed-Kristensen, S. 2015. "Longitudinal observations of globally distributed design teams: The impacts on Product Development." *Proceedings of the 20th International Conference on Engineering Design*, 2015, Milan, Italy.

Authors	Taylor, T. P., Ahmed-Kristensen, S.
Title	A longitudinal study of globally distributed design teams: The impacts on PD
Published in	Proceedings of the 20th International Conference on Engineering Design, ICED 2015, Milan, Italy.
Research aim	Factors influencing success in GPD, such as a lack of common vision or poor documentation are also evident in conventional PD. There is a need to understand how such factors are accentuated in GPD projects to serve as the basis for the development of a support method that supports the selection of KPIs in GPD.
Research stage	Design Research Methodology: Descriptive study I
Research approach	A longitudinal case study (Company A) was conducted to collect information from an industrial GPD project to understand factors influencing success in GPD.
Summary of findings	Team proximity and cultural differences in the GPD team were key causes for a lack of common vision in the team and difficulties in following a common PD process. These difficulties arose during the early planning and concept development stages of the project and resulted in project time delays and design rework during the later stages. Additional controls to avoid such challenges, especially during the early stages of a project, than those suggested in conventional PD are required when managing GPD projects.
Contribution	The paper contributes to the thesis by mapping factors influencing the success of GPD projects according to the stages of development and provides an indication of where they may occur, which enables project managers to set up necessary precautionary actions. Factors influencing success in GPD are accentuated in comparison to conventional PD and there is a need for practical tools to support management. There is a requirement for additional longitudinal observational studies of GPD projects to build a depository of knowledge that supports management in identifying problems early in the process.

A LONGITUDINAL STUDY OF GLOBALLY DISTRIBUTED DESIGN TEAMS: THE IMPACTS ON PRODUCT DEVELOPMENT.

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Abstract

Globally distributing design teams during Product Development is increasingly common across a wide range of industries. Factors impacting the success such as communication, documentation and maintaining a common vision are intensified in comparison to when design teams are co-located. Much of the research towards the impacts on the Product Development process in distributed design teams consists of interviews and observations of short design sessions, with few observational studies focusing on the whole process of Product Development. With the results from a longitudinal observational study and interviews with key members of a project team, this paper investigates the factors impacting the success of Product Development when teams are distributed globally, from the early planning and development phase through to the final testing and refinement. The results indicate an increased requirement for project control strategies during the early phases of Product development to ensure a common vision is maintained throughout the phases of Product Development.

Keywords: Distributed design teams, Project management, Longitudinal study

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1 INTRODUCTION

Factors impacting the success of Product Development (PD) projects are intensified when teams are distributed globally, making it a challenging task for project management to deal with effects on time, cost and quality. It is important for project management to understand when challenges, such as communication difficulties, a lack of common vision between team members or issues related to documentation, may occur during PD projects, enabling them to take the necessary preventative action (Edmondson and Nembhard, 2009). When investigating factors impacting the success of PD, the majority of research in the field of distributed design teams consists of studies involving interviews or observations of short design sessions, typically lasting 1-2 hours (Eris et al., 2014; Scrivener et al., 2003; Hansen and Ahmed-Kristensen, 2011). There are few cases reported in literature of longitudinal observational studies of globally distributed design teams in PD projects. This paper aims to contribute to the further understanding of the factors impacting the success of PD projects when teams are distributed globally. With the results from a longitudinal observational study over 8 months, the factors impacting the success of a globally distributed PD project are mapped across the phases of PD, beginning from the early planning phase and development through to the final testing and refinement. Furthermore, the relationship between the impact factors (IF's) and key parameters for performance is described.

2 LITERATURE REVIEW

The section reviews the literature in conventional PD with particular focus on the factors impacting the success. Following this, the literature on distributed design teams in PD is reviewed. Where possible, observational studies of projects that involve all phases of PD are reviewed; in comparison to those that focus on single phases.

2.1 The Conventional PD process

The process of PD is the sequence of steps or activities that an enterprise employs to conceive, design and commercialise a product (Ulrich and Eppinger, 2011). The sequence of steps varies depending on the context at which the organisation operates. The PD process model referred to in this paper is the generic product development model (Figure 1). The model consists of six, iterative phases from the early planning to the final release of the product to market. After each phase in the process, a gate must be passed before moving to the following phase. The process of PD has been described as a method for controlling the activities associated with PD and reducing risks during PD projects (Cooper et al., 2001).

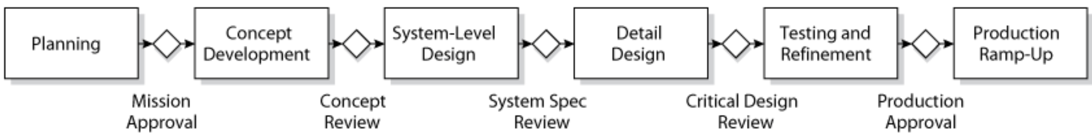

Figure 1.The Generic Product Development Process Model (Ulrich and Eppinger, 2011).

The following key parameters emerge in literature when project managers assess the success of PD projects:

- *Time* - relates to the product development time and is imperative as it allows companies to bring their product to market early.
- *Cost* - relates to both the cost of development and the manufacturing cost of the product and determines profit margins.
- *Quality* – relates to product performance and the extent to which the product meets the demand of the market.

The parameters play a significant role in the eventual success of PD projects and understanding the impacts on these parameters in PD is critical for project management.

2.2 Factors impacting the success: Conventional PD projects

Table 1 lists factors impacting the success of conventional PD at a project level from five independent studies. For each of the longitudinal studies, real time observations were conducted during a project, enabling an in depth understanding of the IF's across all phases of PD (Hales, 1987; Kleinsmann, 2006; Hoegl et al., 2004). This in depth understanding is lacking for the two remaining studies (Edmondson and Nembhard, 2009; Phillips, 1999) as the studies were retrospective in nature and IF's across all phases of PD are not discussed. Although each of the studies investigates the IF's from different viewpoints, many of the factors are inter-related and vary in importance over the course of PD projects. There is an agreement among the authors in Table 1 that teamwork and shared understanding has an impact on the success of PD at a project level. During the longitudinal observational studies (Hales, 1987; Kleinsmann, 2006; Hoegl et al., 2004), quality in relation to both the product and process was found to be a key IF. Furthermore, project management and commitment to the PD projects were considered important factors.

Table 1. Factors impacting the success of conventional PD projects.

Author	Method	Phases of PD	Factors impacting the success of PD
Hales (1987)	Longitudinal observations	Entire PD process	Expertise, Experience, Commitment, Motivation, Systematic design approach, Team productivity, Work quality.
Kleinsmann (2006)	Longitudinal observations	Entire PD process	Information processing, Project documentation, Division of labour, Project planning, Product quality.
Hoegl et al. (2004)	Longitudinal observations	Entire PD process	Interteam coordination, Project commitment, Teamwork quality.
Edmondson and Nembhard (2009)	Literature review	N/A	Project complexity, Team diversity, Temporary membership, Fluid team boundaries, Organisational infrastructure.
Phillips (1999)	Case studies (Interviews)	N/A	Project management, Communication.

2.3 Globally distributed design teams in PD

Since its introduction, the environment where PD takes place has changed and become less predictable (Cooper, 2014). The motivation to reduce development costs, shorten development time and reduce proximity to global customers has seen companies looking to globally distribute their design teams during PD projects. When considering the generic product development model (Figure 1), Hansen and Ahmed-Kristensen (2011) observed that companies look to globalise the later phases of the PD process, with low value adding activities being outsourced and higher value adding activities, such as those in the early phases of PD being offshored. It is well documented that the coordination of design teams, which are globally distributed are not coordinated as easily as those in conventional PD where teams are co-located (Littler et al., 1995; Anderson and Parker, 2012; Emden et al., 2006; Hansen and Ahmed-Kristensen, 2011). Factors impacting the success, such as those in conventional PD (Table 1), are intensified in this global context. Despite this, many companies adopt a learn by doing approach to globally distributed PD projects without clearly understanding the impacts on the key parameters for PD: time, cost and quality (Dabhilkar and Bengtsson, 2008; Kitcher et al., 2013; Hansen and Ahmed-Kristensen, 2011).

2.4 Factors impacting the success: Globally distributed PD projects

Table 2 lists factors impacting the success of globally distributed PD at a project level from four independent studies. Based on the research method, it was difficult to identify factors impacting the success relative to the phases of PD for three of the studies listed in Table 2 (Hansen and Ahmed-Kristensen, 2011; Littler et al., 1995; McDonough et al., 2001). As a result of a longitudinal observational study of an international distributed design project, Scrivener et al. (2003) concluded that although many of the IF's observed were also present in conventional PD projects, the factors were exacerbated during PD projects with globally distributed teams and the need for preventative strategies was evident. However when identifying the IF's, Scrivener et al. (2003) do not highlight where during the PD process the IF's occur. Hansen and Ahmed-Kristensen (2011) found that the challenges experienced during Global PD projects impacted the success; causing time delays, rework and increased resource usage. Results from two surveys (Littler et al., 1995; McDonough et al., 2001) emphasised the need for a higher focus on project management and control during collaborative and global development projects in comparison to conventional PD projects. The common IF's emerging from the studies are communication, cultural differences, project management and technological barriers.

Table 2. Factors impacting the success of PD projects with globally distributed teams.

Author	**Method**	**Phases of PD**	**Factors impacting the success of globally distributed PD projects**
Scrivener et al (2003)	Longitudinal observations	Design briefing, Design analysis, Concept dev, Concept refinement	Communication, Project management, Participation, Culture, Product quality, Technology.
Hansen and Ahmed-Kristensen (2011)	Case studies (Interviews)	N/A	Culture, Knowledge, Coordination, Communication, Organisational structures, Product features, Process features, Lack of common vision.
Littler et al (1995)	Survey (106 respondents)	N/A	Information leakage, Loss of ownership, Different aims and objectives, Development takes longer, Vendor commitment
McDonough et al (2001)	Survey (103 respondents)	N/A	Project management, Communication, Cultural differences, Technological barriers.

2.5 Summary of literature

Given the lack of longitudinal observational studies in literature of globally distributed design teams in PD, it is difficult to gain an overview of where the IF's occur across the phases of PD. For project management to understand when to set up strategies that reduce effects on time, cost and quality, there is a need to understand how the IF's vary over the phases of PD. This is further supported by Scrivener et al. (2003) and Hoegl et al. (2004). The following section describes the methodology adopted for the empirical study conducted to address this need.

3 METHODOLOGY

The following section describes the research questions formed as a result of the literature review, the research approach adopted to investigate the questions and the method employed to collect the data.

3.1 Research Questions

Based on the conclusions drawn in the literature review, the research sought to answer the following questions:

1. How do the factors impacting the success of PD projects vary during the phases of PD when teams are globally distributed?
2. What is the relationship between the factors impacting the success and the key performance parameters in conventional PD: time, cost and quality?

3.2 Research Approach

To answer the research questions, a deep understanding of the natural context in terms of the product, process and organisation was required. Given this and based on similar studies investigating such phenomenon (Hales, 1987; Scrivener et al., 2003), a case study involving direct longitudinal observations of a PD project was conducted (Yin, 2009; Voss et al., 2002). Firstly; this provided sufficient means at which to map the factors impacting the success along the stages of a PD process in real time, and secondly; provided the context knowledge required to investigate the relationship between the IF's and key performance parameters; time, cost and quality in PD.

3.3 Case study

The case study was conducted at a large Danish manufacturing organisation, which specialise in the production of industrial valves and controls for the refrigeration and air conditioning markets. The motivation for the observed project was to re-design an existing product variant to improve the lifetime of the product. The project was conducted by two engineering departments at the company in both Denmark and India. 10 experienced design engineers from both Denmark and India were involved in the PD project. All phases of the PD project were observed including, *Pre-approval, Planning, Concept Development, Detail Design and Testing and Refinement.* A total of 27 meetings were attended including 14 key project milestone meetings over a time period of 8 months. During these meetings, direct observations were made of the globally distributed teams in India and Denmark at each phase of a PD project. The researchers observed the meetings but did not actively participate. Each meeting lasted between 1– 2 hours and was held using an online meeting tool and recorded for later analysis. Detailed notes were kept and each meeting was transferred into a coding scheme, which is described in the following section.

3.4 Interviews

In addition to the observations, 10 semi-structured interviews were conducted with design engineers, whom were involved in the project from both Denmark and India. The results from the interviews were used as a secondary data source and contributed towards a broader understanding of the factors impacting the success of the collaboration retrospectively. The interviewees were asked to describe:

- How the collaboration with the team in India had affected the team in Denmark (and vice versa) in terms of:
  - The organisational setup and the Product Development process.

3.5 Data Collection and Analysis

The development of the coding scheme was an iterative process, beginning with a pre coding scheme and adding new categories as more data was acquired in order to avoid the confinement of data. An example of the coding scheme developed for data collection is pictured in Table 3. First; the stage of development according to the generic PD process described in literature (Figure 1) is indicated in relation to the stage of development in the company's PD process. Second; the strategic level impact factors discussed during the meetings were recorded and later coded according to the impact factors described in literature (Table 1and Table 2). Strategic level impact factors that could not be coded within the impact factors in literature were placed under an "Other" category. Third; the operational level impact factors, which were related to the strategic factors discussed, were recorded and categorised. Finally, the country of origin of the team member raising the impact factor was noted and the criticality of the factor was highlighted. Frequency counts of each impact factor indicated key patterns and relationships in the data. It is important to point out that each impact factor, both strategic and operational level, was counted in respects to frequency discussed and not frequency mentioned. Following this, the qualitative analysis of the indicated patterns provided an understanding of the rationale and theory underlying relationships revealed from the frequency counts. In addition to the coding scheme, field notes were kept during meetings and frequently referred to during the qualitative analysis.

Table 3. Extract from the coding scheme developed.

Stage of PD*	Stage of PD**	Strategic impact factor	Operational impact factor	Raised by	Critical
Planning	Prepare for M1	Lack of common vision	Managing vendor expectations	Denmark	☐
		Knowledge sharing	Lack of Product & Process understanding	Denmark & India	

4 FINDINGS

The company case is described in the following section. The factors impacting the success of the observed PD project are then mapped along the stages of the company's PD process. The relationship between the IF's and key performance parameters; time, cost and quality are described.

4.1 Company background

Over the past decade, the company has established offshore manufacturing and research and development functions in multiple locations worldwide. The focus for the study described in this paper was the collaboration between two engineering departments based in Denmark and India. In 2011, the company established an offshore research and development function in India with the following motivations:

1. To reduce costs – by gaining access to low labour costs of skilled engineers in India.
2. To increase flexibility – by using the additional resources provided by the Indian engineers to free up the time of the Danish engineers, enabling them to work on more complex development tasks.

At the beginning of the collaboration, key members of the Indian engineers received training in products and processes at the site in Denmark. Since 2011, less complex engineering tasks with low risks, such as the conversion of old product drawings to CAD systems, had been offshored to India while larger and more complex development tasks were kept local. Despite the motivations for the collaboration, the engineers have experienced difficulties in coordinating tasks and activities between the site in Denmark and India, with a number of the Danish engineers dissatisfied with the results. The Danish engineers felt the Indian team were working towards quantity based Key Performance Indicators with financial rewards, which was effecting the quality of the converted CAD drawings.

4.2 The globally distributed PD project

Based on these difficulties, a lead design engineer in Denmark decided to include the Indian engineers in a more complex PD project, providing the Indian engineers with more responsibility towards the development activities of an existing product range. This project was introduced with the aim of improving the collaboration between the two teams and is the focus of the results reported in this paper. The project was introduced to the Indian engineers as a "PILOT" project with the aim of providing an example of best practice. Furthermore, the objective was to improve the lifetime of an existing product, maintaining focus on quality solutions rather than quantity. The success of the project would be measured in terms of the amount of resources consumed. The lead design engineer in Denmark recommended they followed a standard operating procedure (SOP) within the company for completing such a project, documenting the steps followed to allow for learnings to be passed on in future projects. The steps followed during the PD project, which relate to the company's SOP for PD projects can be seen in Figure 2. Despite the project being more complex than previous tasks, it was considered by the Danish engineering team to be a relatively simple project, with the amount of consumed resources expected to be kept low.

4.3 Mapping the impact factors along the PD process

The PD process followed during the project is illustrated in Figure 2. Each phase contains a number of deliverables and the stakeholders to be involved during the PD process. The process is comparable to that described in Figure 1, with the exception of:

- The Pre-approval phase:
  - Before the project entered the phases of PD, there was a pre-approval phase, where initial project plans and a product problem analysis were presented to an approval board for a go/ no go decision regarding the project.
- The positioning of gates:
  - There were three key milestones during the project. At each milestone, the team presented the project to an approval board, which made the decision of whether the project could move to the next phase of PD.

The red pointers indicate the factors impacting the success of the project at each phase of the PD process. The green pointers indicate the stage along the PD process that the project team requested external feedback towards the project progress.

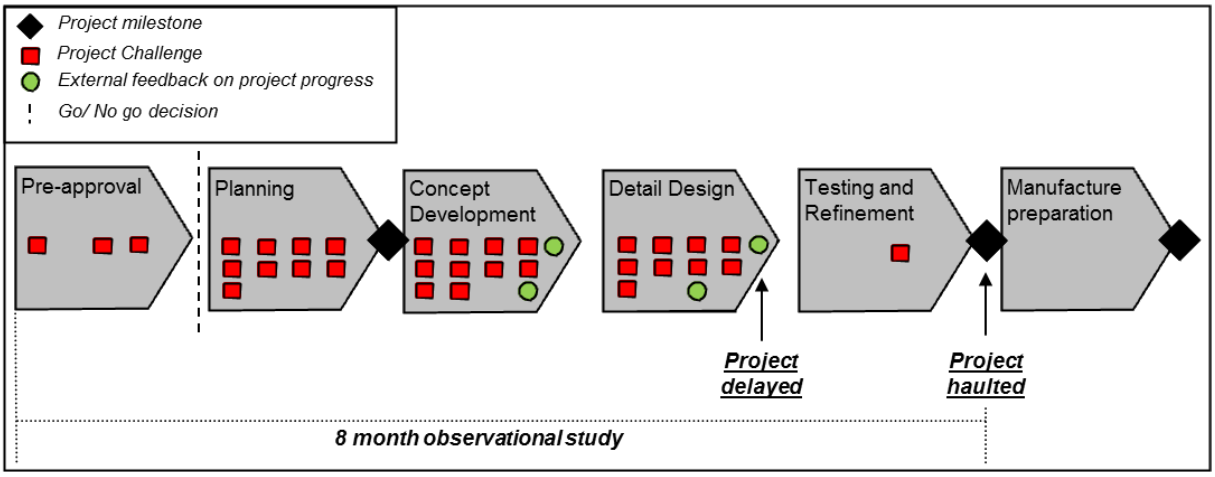

Figure 2. Company PD process, with indication of where impact factors occurred.

After the *Testing and Refinement* phase, the project was halted as other projects at the company took priority, which explains the lack of IF's discussed during the *Manufacture Preparation* phase. Furthermore, the *Testing and Refinement* phase was predominantly conducted at the production site in Denmark, with little involvement from the Indian engineers. The majority of the factors impacting the success were discussed during the *Planning, Concept Development* and *Detail Design* phases. The external feedback was provided at the end of the *Concept Development* and *Detail Design* phases. The feedback was provided by expert design engineers and product technicians who were not involved in the project directly, but were considered knowledgeable toward the product being developed. The final date of the project milestone meeting after the *Testing and Refinement* phase was delayed by two and a half months. The factors impacting the success of the project are illustrated in Figure 3, according to each of the phases of PD pictured in Figure 2. A lack *of common vision* between the Indian and Danish engineers was the factor discussed most frequently during the project with a frequency count of 14. The IF was predominantly discussed during the *Planning, Concept development* and *Detail Design* phase. *Documentation* was the second most discussed IF with a frequency count of 4. Despite only being discussed twice, *standardising tools and procedures* was a factor discussed that the authors considered critical during the project.

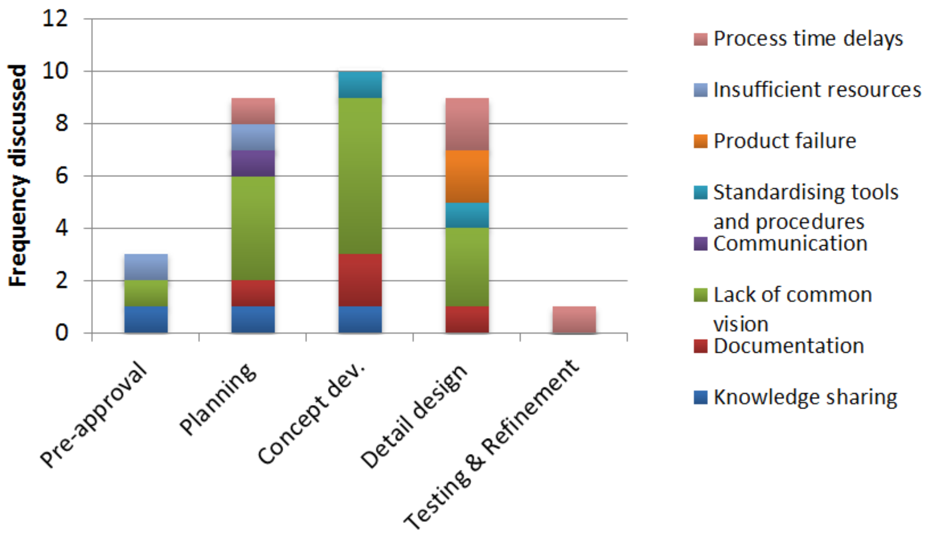

Figure 3. Factors impacting the success of the project at each stage of PD

4.4 Lack of common vision: Managing vendor expectations

During the *Pre-approval* and *Planning* phase, the lead design engineer in Denmark requested the Indian engineers to conduct a root cause analysis, providing 2-3 potential solutions that would improve the product lifetime. This was a deliverable for the first milestone. During the analysis, the

Indian engineer's uncovered additional issues with the product that would have a positive impact on additional product variants, and thereby adding value to the "PILOT" project. A total of 8 potential solutions were presented back to the lead design engineer in Denmark, which the Danish engineer considered being ambitious and outside the main goals and scope of the project, particularly considering the amount of resources required to implement the solutions. The lead design engineer in Denmark reminded the Indian engineers of the expectations for the project and lowered the ambition levels for the project accordingly. The Indian engineers agreed and the project was approved by the approval board at the first milestone meeting. Despite this, during the *Concept Development* and late in the *Detail Design* phase, the Indian engineers continued to push for the solutions, which positively impacted additional product variants. The Indian engineers were interested in increasing the value of the project, while the Danish engineers were interested in working efficiently towards improving the initial problem with the product. Late in the *Concept Development* and *Detail Design* phase, the lead design engineer invited a number of expert design engineers to provide their feedback on the proposed solutions and the progress of the project. The feedback they received was to focus on improving the lifetime of the single product variant by making a small number of design changes and hence, ensuring resource consumption was kept low.

The misalignment of work completed by the Indian engineers with the expectations communicated by the Danish engineers was a key cause for the second project milestone being delayed by two and a half months. The project represents a case where coherence between project goals in Denmark and India was lacking, which is described as a key factor impacting the success of globally distributed PD projects (Table 2). One possible explanation for this was the Indian engineers were aware the project was a "PILOT" project and therefore, applied additional resources than was necessary for the project in order to prove their value. Furthermore, the role of project manager was assigned to a skilled design engineer in Denmark. Project management is a factor impacting the success of conventional PD projects (Table 1) and when managing globally distributed teams, the requirement for project management is increased (Eppinger and Chitkara, 2009). In the case presented, the need for greater project management competencies for the globally distributed PD project was evident. Managing the Indian engineers' expectations was an issue discussed in the early phases of the project. However, the feedback from the expert design engineers was not provided until late in the project, at which time the in depth analysis had already been performed by the Indian engineers. Involving the feedback earlier in the project may have identified the *lack of common vision* in the team, enabling the Danish project manager to take necessary preventative action. Furthermore, as the project progressed, the lack of prioritisation of the project against other more complex PD projects was evident as the project was down-prioritised and halted after the *Testing and Refinement* phase was complete. This was highlighted as a risk for the project in the *Planning* phase of the project.

4.5 Standardising tools and procedures: Alignment of processes

Before the project commenced, the lead design engineer in Denmark suggested the project team follow the SOP developed in the company for the completion of the PD project. The SOP was used during meetings throughout each phase of the PD process by the lead design engineer as an approach to steer the tasks and activities required for the progression of the project. However, from the early *Planning* through to the *Detail Design* phase, the Indian team preferred to plan their activities according to a six sigma process, which the Indian engineers had recently received training in. This caused for further misalignment between the work completed in the project team and the deliverables documented in the SOP. This can be linked to the IF highlighted earlier: *A lack of common vision*. The lead engineer in Denmark attempted to document the project according to the SOP in order for learnings to be carried over to future projects. However, the Indian engineers approached the project as an opportunity to build their competencies in using the six sigma process. This appeared to cause tension between the lead design engineer in India and the lead design engineer in Denmark as the Indian team felt the six sigma process complimented the SOP. Ensuring process modularity during globally distributed PD projects is one of ten, key success factors highlighted by (Eppinger and Chitkara, 2009). The misalignment of processes in the project made it difficult for the lead design engineer in Denmark to monitor tasks and activities between the two teams.

In summary, the case described highlights that *a lack of common vision* between globally distributed teams in PD is a key factor impacting the success of PD projects; causing time delays and increased resource usage. To prevent these issues, it is important to include feedback from stakeholders outside of the project during the early phases of PD projects. This would potentially enable project managers to identify factors impacting the success of a project and take necessary preventative action. The *lack of common vision* was also evident based upon the existing collaboration prior to starting the project observed, where it was felt a number of the Indian engineers were working towards high-level, quantity driven Key Performance Indicators, which had a negative impact on the quality of the work completed. Furthermore, ensuring a project team has the required project management competencies is a factor impacting the success of conventional PD (Table 1). In globally distributed PD development teams, the required competencies are extended and experience working with engineers from culturally different backgrounds is important. Additional controls, especially during the early phases of a project, than those suggested in conventional PD are required when managing globally distributed PD projects. When considering the goals of the project at the outset, it is difficult to label the project a success as the amount of resources consumed, in terms of time, was greater than expected.

4.6 Comparisons with Conventional PD

The process of PD has been described as a method for controlling the activities associated with PD and reducing risks during projects (Cooper et al., 2001). The PD process followed during the completion of the project was comparable to the generic PD process described in literature. Despite following this process, the globally distributed team experienced issues related to a *lack of common vision*, suggesting a need for an increased level of control in the early phases of PD to ensure project level goals are aligned. When considering the key parameters time, cost and quality in conventional PD, Rosenau (1993) described the parameters as being mutually exclusive. However, based on the findings from the case study described, the authors argue that the parameters are highly inter-related and the factors impacting the success in globally distributed PD projects add further complexity. *A lack of common* vision between the two teams at a strategic level led to a misalignment of work completed with the expectations communicated at an operational level. This was evident both in terms of the project described, and the issues with quality versus quantity before the project commenced. These factors impacting the success of the collaborations and caused time delays during the project, and quality issues with work completed. The effects on time and quality led to increased resource usage, which is associated with increased costs.

4.7 Limitations

The single case study approach undertaken is one of very few longitudinal studies conducted of globally dispersed teams, with the strength of real tasks and activities being observed in an industry setting. However, this also means that single factors such as culture or distance cannot be blocked as in experimental studies. Despite this, the benefits of our approach outweigh the limitations.

4.8 Conclusion

The paper investigated factors impacting the success of PD projects when teams are globally distributed. From the literature review, there was a lack of longitudinal observational studies in globally distributed teams, which focussed on all phases of PD; from the early planning and development through to the final testing and refinement phase. To address this, an 8 month longitudinal observational study was conducted, providing an overview of the factors impacting the success across the phases of a PD project. A *lack of common vision* between the teams in Denmark and India, particularly during the *planning, Concept Development* and *Detail Design* phases of the project was a key cause for time delays during the project. Involving feedback from design experts earlier in the process may have allowed the project team to avoid such delays. Difficulties in following a common procedure during the early phases of the project further added to the time delays. By building on previous work in the area and utilising aspects of established methodologies from PD, this paper provides an understanding of the factors impacting the success of PD projects when teams are globally distributed, providing an overview of where along the PD process the impact factors occur. For future research, there is a requirement for additional longitudinal studies in globally distributed teams that map the factors impacting the success across the PD process. This will provide project managers with an overview of when the factors may occur during PD, enabling them to set up strategies that reduce effects on time, cost and quality.

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Appendix 5.6 Paper VI

Status: Submitted to the International Journal of Operations & Production Management.

Authors	Taylor, T. P., Ahmed-Kristensen, S.
Title	Globally distributed design teams: The impacts on product development
Submitted to	International Journal of Operations and Production Management, Emerald, ISSN: 0144-3577.
Research aim	Factors influencing the success in GPD are accentuated in comparison to conventional PD and issues related to team proximity and cultural differences ensure that managers approach such projects differently. There is a need to understand the adjustments management make when dealing with GPD projects and the influence this has on success. This serves as the basis for the development of a support method that supports the selection of KPIs in GPD.
Research stage	Design Research Methodology: Descriptive study I → Prescriptive study.
Research approach	2 longitudinal case studies (Company A and Company B) were conducted to collect information from 3 industrial GPD projects to investigate how management approach GPD projects and the influence this has on success.
Summary of findings	Adjustments were made in relation to the level of governance and modularisation of the PD process and product in order to manage issues related to cultural misunderstanding and team proximity. The adjustments impacted the complexity of tasks, alignment of interests and the workload of the project managers, both positively and negatively. The opportunity to collocate members of the global team was found to reduce the negative influences on GPD.
Contribution	The paper contributes to the thesis by developing an understanding toward the cause-effect relationship of factors influencing the success in GPD projects, which enables factors to be linked to their initial causes and hence, supports with identifying where preventative strategies require developing to support the transition from conventional to globally distributed PD.

Globally distributed engineering teams: impacts on product development

Abstract

Purpose - The migration from local, cross-functional product development (PD) to globally distributed PD (GPD) represents a major transformation in industry and understanding the impacts on the PD process is vital.

Design/ methodology/ approach - Two in-depth longitudinal case studies with Danish manufacturing companies with established offshore R&D facilities in India, China and Poland provide unique insight towards the key factors influencing success in three GPD projects.

Findings - Controls applied to mitigate the risk of project failure, including the level of project governance and the composition of PD activities, impacted the complexity of tasks, the alignment of interests and workload of the project managers, which were key factors influencing success in the observed GPD projects.

Practical implications – Providing global partners with sufficient responsibility towards clearly defined PD tasks, whilst maintaining task stability, and collocating team members during planning stages of GPD projects is important to support project commitment and reduce the need for overt managerial authority when coordinating GPD projects.

Originality/ value - The study adopts a multiple longitudinal case study approach, which is one of few studies conducted in an industry setting that focus on real engineering design activities in a global context. The longitudinal appproach enables observed influence factors to be traced back to initial causes, informing researchers and practitioners regarding the necessary precautionary strategies to develop to better manage the impacts and support the transition from local, cross-functional PD to GPD.

Keywords – Global operations management, New product development, Case studies

Paper type – Research paper

1. Introduction

In comparison to local, cross-functional product development (PD) where engineering teams are typically collocated, global product development (GPD) involves the development of products between culturally diverse and geographically dispersed engineering teams (Eppinger and Chitkara, 2009). Companies that adopt GPD are driven by opportunities to reduce PD costs by utilising skilled engineers in low cost regions, reduce proximity to global markets or increase understanding towards global customer needs (Eppinger and Chitkara, 2009; Verdecho, 2009). However, managing globally distributed teams during PD is challenging and previous studies highlight how companies encounter difficulties in relation to cultural misunderstandings, creating a common vision or standardising company procedures (Kalyandurg and Akhilesh, 2012; McDonough, 2001). Despite such challenges, companies have been observed to adopt a learning-by-doing approach with solutions to difficulties implemented on an as-needed basis during the GPD process (Hansen and Ahmed-Kristensen, 2011), which suggests the challenges that influence success are not yet understood. Previous studies that investigate the global dispersion of engineering teams during PD typically consist of interviews or observations of short design sessions that focus on specific stages during the PD process (Hansen and Ahmed-Kristensen, 2011; Eris *et al.*, 2014; Yam and Chan, 2015). The need to investigate GPD with longitudinal studies, which provide the in-depth insight required to trace difficulties back to their initial causes and hence, inform management of where along the process precautionary strategies require implementing has been highlighted (Andersson and Pedersen, 2010; Huang *et al.*, 2009).

This paper aims to develop an understanding towards the key factors that influence success when managing PD projects with globally dispersed engineering teams. To investigate this, the literature review draws on two fields, namely: engineering design where key factors influencing the success in local, cross-functional PD and GPD are reviewed and; operations management where key approaches for managing GPD are reviewed. Based on this, the research questions are formulated and the research method is described. Two in-depth longitudinal case studies with large Danish manufacturing companies were conducted with a focus on engineering design activities in three GPD projects. Following this, the cause-effect relationships of the key factors influencing success in three GPD projects are presented. Based on the analysis, propositions are formulated and discussed in respect to available literature, with the managerial and theoretical implications outlined. Finally, the paper concludes with clarifications towards the theoretical contributions, the limitations of the study and directions for future research.

2. Literature review

The theoretical underpinning of this paper draws on two fields of study, namely: engineering design, where key factors influencing success in local, cross-functional PD projects and GPD projects are reviewed and; operations management; where key approaches for managing GPD projects are reviewed.

2.1 The product development process

For a company to conceive, design and commercialise a product, a PD process comprising a sequence of stages is often employed, from early planning through to final testing and refinement before production ramp-up. In this paper, the process illustrated in Figure 1 for PD is the main reference as this is among the most commonly used in manufacturing companies. Success in PD projects is often determined based on the effectiveness and efficiency of the PD team to develop a product to the specified quality, within the budgetary requirements and within the proposed time constraints (Hales, 1987; Hoegl *et al.*, 2004; Krishnan and Ulrich, 2001; O'Donnell and Duffy, 2002). The factors that *influence* success, however, are highly dependent on the environment in which PD operates and the many different stakeholders involved during the process (Hales, 1987).

During observations of an engineering design project, Hales (1987) identified over 100 critical factors that contributed to PD success and Badke-Schaub and Frankenberger (1999) identified 265 critical situations to which they assigned 34 key factors influencing success, highlighting the complexity of this topic.

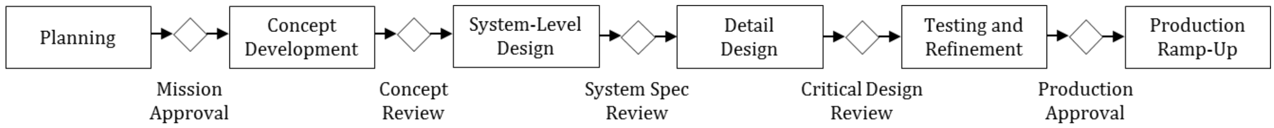

Figure 1 The generic product development process (Ulrich and Eppinger, 2011)

To identify key factors influencing success along the PD process and provide a meaningful interpretation of the results, the literature review in this paper focuses on previous studies that provide a rich understanding towards real tasks during the completion of PD projects in an industry setting, i.e. observational studies of PD projects in industry rather than experimental studies with students, where the environment is often more controlled. Furthermore, only *critical* factors influencing the success, as described by authors in the reviewed studies were included. As a result, key articles from journals in engineering design and operations management were reviewed and 17 key influence factors were identified. Similar to previous studies (Hales, 1987; Badke-Schaub, 1999), key factors identified during the review were grouped according to the following influence categories, allowing for comparison across studies:

- The Individual/ Task –tasks conducted by the PD team for the development of the product.
- The Team –group of design engineers responsible for the development of the product.
- The Process –sequence of steps employed to conceive, design and commercialise a product.

The identified factors are presented in Table 1 and discussed in more detail according to the influence categories in the following section.

2.2 Local, cross-functional product development projects: factors influencing success

At the individual and task-level, the complexity of tasks during PD projects has been associated with project motivation and commitment, which were found to be key moderators for PD success (Brown and Eisenhardt, 1995; McDermott, 1999; Hoegl *et al.*, 2004). For example, during a longitudinal study of PD projects McDermott (1999) observed that in projects where task complexity was high; the level of uncertainty and ambiguity increased and teams looked to incorporate knowledge from various functional disciplines, bringing rise to new opportunities and increasing innovation in order to efficiently handle tasks. In PD projects where task complexity was low, Van Oorschot *et al.*, (2005) found that work packages were likely to be more stable and risks related to project time delays and required resources were reduced. However, low task complexity was negatively associated with project commitment and motivational attributes as team competencies were not fulfilled. Based on observations of multiple R&D projects, Hoegl *et al.*, (2004) conclude that it is important to adjust the level of task complexity in accordance with the technical competencies within the project team to support inter-team coordination and project commitment. The complexity of tasks shapes the environment where PD takes place in terms of its uncertainty or stability and should be representative of the competency levels in the project team.

At the team-level, the importance of communication and coordination during the completion of PD projects has been highlighted (Badke-Schaub and Frankenberger, 1999; Reid, 2000). For example, during the analysis of design projects Badke-Schaub and Frankenberger (1999) observed that informal communication within the team created a “good group climate” and supported team integration, which translated to economic value in terms of time-saved in the projects. According to Krishnan and Ulrich (2001), the project manager plays an important role in coordinating such involvement and managing communication both internally and externally from the project team. In Brown and Eisenhardt’s study (1995), the project manager influenced the organisation of work in the PD team, which in turn impacted the performance and effectiveness of projects. In the most successful projects reported, the senior management only applied subtle controls to projects, providing team members with the freedom to work autonomously. Furthermore, Macmillan *et al.*, (2001) and Charnley *et al.*, (2011) found that ensuring the alignment of interests during early stages of PD between the involved parties was critical in avoiding inefficiencies later in the process.

At the process-level, a clear understanding towards the systematic approach for PD projects within the project team, such as the stages illustrated in Figure 1, was found to be important. For example, during a longitudinal study of an engineering design project Hales (1987) found that such understanding increased motivation towards the completion of design tasks and supported management with the prioritisation and coordination of tasks. Furthermore, the decision making process in PD projects has frequently been described as a key cause for project time delays and is dependent on many of the factors illustrated in Table 1. Badke-Schaub and Frankenberger (1999) and Jerrard *et al.*, (2008) found that a slow decision making process was a consequence of low availability of information at the company and the role played by the project manager.

The identified factors are highly inter-related across the different influence categories. Understanding the impacts of such factors on PD projects helps support the development of precautionary strategies along the PD process (Badke-Schaub and Frankenberger, 1999). However, advancements in communication technologies has altered the environment where PD takes place and opportunities to reduce costs, shorten development time or access new resources has resulted in companies globally distributing parts of their PD process. The impact this transformation has on PD projects is discussed in the following section.

Influence category:	Influence factor:	Example of impact at the project-level:	References:
Task/ Individual	Experience	Availability of information to solve design tasks.	(Badke-Schaub and Frankenberger, 1999; Charnley *et al*., 2011; Macmillan *et al.*, 2001)
	Individual characteristics	Quality of teamwork in the project team.	(Charnley *et al.*, 2011; Jerrard *et al.*, 2008)
	Commitment	Willingness to perform towards project objectives.	(Hoegl *et al.*, 2004)
	Task complexity	Level of commitment within the project team.	(Jerrard *et al.*, 2008; Van Oorschot *et al.*, 2005)
Team	Team integration	Openness of exchange of ideas within the project team.	(Badke-Schaub and Frankenberger, 1999; Hales, 1987; Reid, 2000)
	Forming and sustaining partnerships	Access to multiple perspectives and innovation opportunities.	(Charnley *et al.*, 2011)
	Alignment of interests	Amount of design rework and disputes.	(Charnley *et al.*, 2011; Macmillan *et al.*, 2001)
	Project management	Level of autonomy within the project team.	(Brown and Eisenhardt, 1995)
	Coordination	Availability of information and team performance.	(Hoegl *et al.*, 2004)
	Team competencies	Amount of risk involved with the completion of a project.	(Hales, 1987; McDermott, 1999)
	Communication	Communication channels and availability of information in the project team.	(Reid, 2000)
	Senior management	Balance between adequate intervention and oversight within the project team.	(Brown and Eisenhardt, 1995)

	Project team organisation	Availability of information and communication in the project team.	(Brown and Eisenhardt, 1995; Macmillan *et al.*, 2001)
	Motivation	Level of performance (effectiveness and efficiency) within the project team.	(Hales, 1987)
Process	Availability of information	Availability of physical or electronic information to support communication.	(Badke-Schaub and Frankenberger, 1999; Crabtree *et al.*, 1997)
	Decision making process	Time taken to receive feedback from the project manager.	(Badke-Schaub and Frankenberger, 1999; Jerrard *et al.*, 2008)
	Systematic design approach	Level of integration and alignment of tasks of project team.	(Hales, 1987; Reid, 2000)

Table 1 Identified influence factors in local, cross-functional PD and the impact on PD projects

2.3 Globally distributed product development projects: factors influencing success

In comparison to local, cross-functional PD, research towards GPD is less mature and the impacts on PD projects in practice are not well understood (Cheng *et al.,* 2015; McDonough *et al.,* 1999; McDonough *et al.,* 2001) with many companies adopting a learning-by-doing approach to managing such projects (Hansen and Ahmed-Kristensen, 2012; Kitcher *et al.*, 2013). Despite this, there is consensus in literature that issues related to cultural diversity and team proximity accentuate factors impacting the success at a project-level, such as those in Table 1, and tasks and activities are not coordinated as easily (Anderson and Parker, 2012; Emden *et al.,* 2006; Hansen and Ahmed-Kristensen, 2011; McDonough *et al.,* 2001; Sosa *et al.,* 2004). For example, in an environment where close physical proximity is lacking and frequent, spontaneous interactions are not so easy, previous studies highlight how complex tasks become more difficult to manage and design rework increases (Eppinger and Chitkara, 2009; Hansen and Ahmed-Kristensen, 2011; Kalyandurg and Akhilesh, 2012). Furthermore, a lack of frequent interaction between culturally diverse members makes for a challenging environment when identifying and managing conflicts and ensuring the alignment of interests within GPD teams. Frequent and spontaneous interactions have been found to support shared understanding in a form of local, cross-functional PD (Kleinsmann and Valkenburg, 2008; McDonough *et al.,* 2001) and the need for communication quickly, richly and with high volumes of information to support the alignment of interests increases in GPD (McDonough *et al.,* 1999). Given this, the time required for project management to coordinate such PD projects increases. Crabtree *et al.,* (1997) found that activities involving coordination in GPD projects occupied 69% of an engineer's time and Littler *et al.*, (1995) highlight how the maintenance of the collaborations often becomes the prime objective rather than the development of the product itself. During their investigations of GPD projects, Kalyandurg and Akhilesh (2012) and McDonough *et al.,* (1999) found that increases in workload for project management negatively impacted the speed of the decision making process, which in turn led to frustration with global partners and resulted in project time delays.

While physical proximity can reinforce social similarity, shared values and expectations, distance between team members can lead to significant declines in communication and interaction. The studies exemplify how migrating from local, cross-functional PD to a form of GPD accentuates factors such as those identified in Table 1 as team proximity and cultural differences become increasingly significant.

2.4 Managing globally distributed product development projects

To effectively manage GPD projects, a recent trend has seen companies attempting to decompose their PD process and products into globally distributed work packages to enable distributed design teams to work autonomously and alleviate the need for overt managerial authority when coordinating tasks (Eppinger and Chitkara, 2009; Johnsen, 2011; Hansen and Ahmed-Kristensen, 2012). BusinessWeek Research Services (2006) reported that the majority of leading firms in their study had decomposed their PD processes and procedures to better support the integration of GPD activities. Although decomposing both the product and process can provide support in managing GPD projects, the interfaces and connectivity between the distributed packages must be clearly defined. Kalyandurg and Akhilesh (2012) observed that without clearly defined interfaces, feedback was often delayed for interrelated work packages causing frustration among global partners.

Balancing the level of project governance, while providing global partners with sufficient responsibility towards development tasks, remains a unique challenge for GPD projects and is important when managing such projects (Kalyandurg and Akhilesh, 2012). Previous studies highlight how companies routinise PD tasks for their global partners in a bid to stabilise the PD environment, reduce the risks of project failure and avoid cultural misunderstandings (BusinessWeek Research Services, 2006; Hansen and Ahmed-Kristensen, 2011). However, the level of empowerment and freedom to develop in GPD teams is important when involving skilled engineers and has been found to assist in building a climate of trust (Kalyandurg and Akhilesh, 2012). Furthermore, the inclusion of global partners during decision making in the early planning stages of GPD projects has been described as a technique for avoiding the misalignment of interests and ambiguity during the later stages (Kleinsmann and Valkenburg, 2008; Littler, 1995; McDonough et al., 1999).

2.5 Summary of literature and research questions

The review highlighted the difficulties companies face during the migration from local, cross-functional PD to a form of globally distributed PD and some of the key approaches for managing this transformation. However, the majority of studies that investigate GPD consist of interviews or observations of short design sessions and focus on specific stages during the PD process (Hansen and Ahmed-Kristensen, 2011; Eris *et al.*, 2014), and the learning-by-doing approach to GPD suggests there remains a lack of understanding towards the key challenges that influence success along the PD process. To develop this understanding, there is a need for longitudinal studies of GPD projects that provide the in-depth insight required to trace difficulties back to their initial causes and hence, inform management of where along the process precautionary strategies require implementing. The need for such studies is further supported in literature (Andersson and Pedersen, 2010; Huang *et al.*, 2009). As such, the research sought to answer the following questions:

1. What are the key approaches for managing product development projects with globally distributed engineering teams?
2. How does the globalisation of product development influence success at the project-level?

3. Methodology

The aim of the research study was to understand how management approach PD projects with globally distributed engineering teams and to develop an in-depth understanding towards the key factors influencing success along the process. To investigate this, case studies were carried out with two large, Danish manufacturing companies with offshore R&D facilities in India, China and Poland with a focus on three GPD projects. Case studies were considered the most appropriate research approach given the exploratory nature of the research questions. In addition, case studies provide the in-depth understanding required to determine the link between cause and effect, which is otherwise difficult in survey research (Voss *et al.,* 2002). However, the natural setting where the case studies were conducted made it difficult to control the environment and as such, variables such as cultural differences or team proximity could not be controlled that could otherwise be controlled in a laboratory setting. Despite this, case studies carried out in their natural environment provide in-depth understanding of real time tasks and activities that lead to creative insights of high validity for practitioners (Voss *et al.,* 2002). The data collection methods employed during the case studies were threefold and included: 1) 21 semi-structured interviews; 2) 34 direct observations during project meetings, and; 3) the collection of company documentation, and form the empirical results reported in this paper. The interviews provided understanding towards key challenges encountered during the global collaborations under investigation and the approaches for managing GPD projects and could be used to capture data retrospectively. The observations provided the in-depth understanding to investigate the key factors influencing the success during GPD at the project-level and the time-causal relationship of events along the PD process. In addition to triangulating the results within the cases studies and hence, strengthening the reliability and validity of the results (Meredith, 1998), the documents collected provided supporting information toward company and project procedures during the case studies.

A description of the case companies is presented in the following sections, followed by the approach for data collection and analysis.

3.1 Company case characteristics

The companies were selected from a previously established interest group, including 65 Danish manufacturing companies, characterised by their high involvement with GPD. The criteria for selection were based on the fulfilment of the research aims and practicality and included:

- The company should be a large Danish manufacturing company with their headquarters in Denmark to increase the accessibility of information during the research study.
- The company has a recently established offshore R&D facility in a low cost country, such as China, India or Poland.
- The offshore R&D facility is highly involved during the development of products.

Table 2 illustrates key characteristics of the two case companies selected for this research study and are discussed in more detail in the following sections.

Company characteristics	**Company A**	**Company B**	
Headquarters based in:	Denmark	Denmark	
Industry sector:	Refrigeration & air conditioning	Pharmaceutical	
No. of employees:	24,000 employees global	2,700 employees global	
Turnover:	34 billion DKK (in 2012)	3,4 billion DKK (in 2010)	
Offshored R&D facilities involved in study:	India	China	Poland
No. years offshored R&D established at study time:	2.5	1.5	0.8

Table 2 Company case characteristics

3.1.1 Company A

The company specialise in the production of industrial valves and controls for the refrigeration and air conditioning markets. In 2011, the company established an offshore R&D facility in India with the motivation to reduce costs by gaining access to low labour costs of skilled engineers in India. However, since the collaboration began the Danish engineers experienced difficulties during PD projects with the Indian engineers and a number of tasks and activities were neither completed on time nor to the desired quality. The motivation of the Indian engineers towards the tasks and activities, which were routine in nature, was seen as a contributing factor to these difficulties and therefore, a lead engineer in Denmark took the decision to involve the Indian engineers as the ‘main drivers’ in a more complex PD project in an attempt to increase motivation. This GPD project, from the early planning through to the final testing of the product, forms the basis for the results reported in this paper for Company A and the project is described in more detail in the next section.

Project I: the objective of the project was to improve the performance of an existing valve by increasing the product lifetime. The project was introduced to the Indian engineers as a 'Pilot' project and the solution was known by the Danish engineers with the primary aim to improve the collaborations, whilst keeping risk low. The project was expected to last three to four months and followed the stages in the standard PD process at the company (Figure 2). The project involved 10 experienced mechanical engineers from the R&D facilities in India and Denmark (see Table 3 for characteristics of Project I).

Figure 2 Company A: Product development process followed in Project I

3.1.2 Company B

The company specialise in the development and manufacture of blood analysis instruments, such as blood gas analysers and syringes for the pharmaceutical industry. The company operates globally and has recently established R&D facilities in Poland and China with the motivation to reduce costs by gaining access to skilled engineers in low cost regions. Collaborations between the R&D

facilities between: 1) China and Denmark and; 2) Poland and Denmark during two GPD projects form the basis for the results reported in this paper for Company B and the two projects are described in more detail in the next section.

Project II: the objective of the project was to develop a new blood gas analyser, enabling doctors and nurses to retrieve more blood samples in a given time frame. The product to be developed was complex with 15 different modules consisting of 15-20 different parts, involving a total of 14 mechanical engineers from the Danish and Chinese R&D facilities. The project followed the stages in the standard PD process at the company (Figure 3). As the project was still ongoing at the end of this research study, investigations were made during the first three stages of Project II with the expected project duration set to four years (see Table 3 for the characteristics of Project II).

Project III: The objective of the project was to redesign a current syringe, making it aspirating rather than venting and therefore, impact a variety of products in the company’s portfolio. The product to be developed was less complex than in Project II, involving a total of 13 engineers from the Danish and Polish R&D facilities with the project following the stages in the standard PD process at the company Figure 3. As the project was still ongoing at the end of this research study, investigations were made during the first three stages of Project III with the expected project duration set for two years (see Table 3 for the characteristics of Project III).

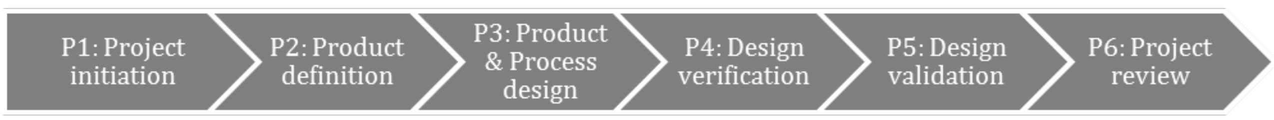

Figure 3 Company B: Product development process followed in Project II and III

	Company A	Company B	
Project characteristics	**Project I**	**Project II**	**Project III**
Product to be developed	Industrial valve	Blood gas analyser	Syringe
Product complexity	Low	High	Low
Expected duration of project	4 months	4 years	2 years
PD stages investigated*	P1, 2, 3, 4 & 5	P1, 2 & 3	P1, 2 & 3
Offshored R&D site involved in project	India	China	Poland
Years R&D established at time of study	2.5	1.5	0.8

**Note: See Figure 2 and Figure 3 for PD project stages*

Table 3 Project characteristics at Company A and B

3.2 Data collection methods

Data were collected over an 18-month period at the case companies. The participants during the three projects primarily consisted of mechanical and design engineers. Top-level management involved in the projects were also observed less frequently. The data collection methods are described in more detail in the following sections (see Table 4 and Table 5 for characteristics of the data collection methods).

- For the observations, 34 project meetings across the three GPD projects at Company A and B were observed, lasting approximately 60 minutes. The researchers observed the meetings but did not actively participate. Confidentiality agreements restricted the researchers from recording all meetings. Field notes structured according to the research aims of this paper were taken during the meetings and later transferred into a coding scheme for further analysis, which is described in section 3.2. For Project I, an eight-month observational study from P1 to P5 was conducted (see Figure 2 for stages of project). Given the time constraints of the research study and the ongoing status of Project II and III, a one-month observational study was conducted for Project II during P3 and a three-month observational study for Project III during P1 – P3 (see

Figure 3 for stages in Project I and II). Despite this, interviews and document analysis allowed the researchers to investigate the projects retrospectively.

- For the interviews, 21 semi-structured interviews were conducted with participants from Company A and B, typically lasting between 45 – 60 minutes. The participants were selected based on their involvement with the projects under investigation. An interview guide was used with all interviewees with slight adjustments depending on the interviewee’s experience. For example, all interviewees were asked to provide basic background information about their respective global collaborations and the key challenges encountered during the completion of PD projects. In addition, the Danish interviewees were asked to describe the approach for managing the GPD projects described in the previous section. The interviews were audio recorded, transcribed and transferred into a coding scheme for further analysis (described in section 3.2).
- Company and project documentation such as detailed project plans, risk assessments, key project metrics and meeting minutes that formed part of the routine tasks for the GPD projects were collected and organised to highlight facts and events during the projects.

		Company A	**Company B**	
		Project I	**Project II**	**Project III**
	No. of participants	10	14	13
	Offshored R&D facility involved	India	China	Poland
	No. of observations	27	3	4
Observations:	Length	60 minutes	60 minutes	60 minutes + 2 day workshop
	Time span of observations	8 months	1 month	3 months
	Location	Online	Online	Face-to-face

Table 4 Characteristics of observations conducted at Company A and B

		Company A	Company B
Interviews:	No. of interviewees	12 (8 Danish engineers, 4 Indian engineers)	11 (3 Danish engineers, 6 Chinese engineers, 2 Polish engineers)
	Location	3 Face-to-face (with Danish engineers), 9 Online (5 with Danish engineers, 4 with Indian engineers)	9 Face-to-face (3 with Danish engineers, 6 with Chinese engineers), 2 Online (with Polish engineers)
	Length	45-60 minutes	

Table 5 Characteristics of interviews conducted at Company A and B

3.3 Data analysis

A coding scheme was developed as the research study progressed for the analysis of the empirical data collected with key aspects drawn from Braun and Clarke (2006) for the coding of data. Codes were developed based on key themes that emerged from the literature review and interesting features within the empirical data; so as to avoid the confinement of data. The transcriptions from the interviews and field notes from the observations were analysed and categorised according to the codes in the coding scheme (see Table 6 for an excerpt from the coding scheme). The themes were reviewed for mutual exclusivity and the codes reviewed for their coherence within the themes. A coder-reliability check was conducted with a research associate involved in the research study, which indicated a strong validation coefficient: 0.78, i.e. the coding of the data was not subjective. Code frequency counts and code co-occurrence were used to generate scores for the management approaches, their relation with the identified project influence factors and the impact on the GPD projects. The impact of the identified influence factors on the GPD projects was measured in terms of project time delays with the relative contribution estimated by comparing factors within and across multiple projects. A data matrix, developed based on similar studies (Mello *et al.*, 2015), was generated to visualise and compare the scores across and within the investigated projects. Key patterns were identified and analysed qualitatively, which supported the development of propositions and provided an understanding of the rationale and theory underlying relationships. According to Dul and Hak (2008), theory building research aims at developing new propositions based on the analysis of instances of the object of study.

Theme	Code (sub-code)	Definition
Key challenge	Type (Communication)	Difficulties with communication between the Danish and global R&D.
Management approach	Type (Project governance)	Level of control applied in the GPD project in order to mitigate the risk of project failure.
Project influence factor	Type (Task complexity)	Complexity of the tasks and activities of the global R&D teams in relation to the product to be developed.
Impact on PD	Type (Time delays)	Impact the influence factor had on the GPD project in terms of project timing.
PD stage	Stage (Planning)	Stage at which the impact factor occurred.

Table 6 Example of codes used for data analysis

4. Findings

Key challenges encountered during early collaborations with the global R&D facilities at Company A and B are presented in the following section. Furthermore, the cause-effect relationships of key factors influencing the success during the three observed GPD projects are presented. The findings are discussed in relation to relevant literature in the discussion section of this paper.

4.1 Key challenges with globally distributed product development

Key challenges encountered during collaborations with the global R&D facilities at Company A and B are illustrated in Figure 4 and Figure 5 according to the frequency they were stated during the interviews and the cumulative percentage of the frequency counts to allow for comparison across the two companies. Difficulties with *Communication* and *Cultural differences* were key challenges encountered and accounted for 51% of the total frequency counts at Company A and 58% at Company B and the key challenges are further exemplified here.

- *Communication* - a lack of clear task specifications provided by the Danish engineers at Company A and B resulted in the need for additional information for engineers at the global R&D to complete PD tasks and hence, influenced their ability to work autonomously. However, the availability of information to complete tasks was not easily obtained given the geographical dispersion of the R&D facilities, the different time-zones and the lack of a Danish representative at the global R&D facilities. This resulted in time delays and frustration among engineers at the global R&D facilities as the engineers would often be waiting for additional information before they could progress with PD tasks and is exemplified in the following quotation: *"It will take a day for the Danish engineers or even in some cases it has taken a week for them to reply… When we requested for the process to follow for manufacturing the components, we did not have any immediate answer and they did not have any immediate document to share."* Chinese engineer, Company B.
- *Cultural differences* - the low degree of autonomy, which typically characterises the working environments in countries such as China and India, in comparison to the high degree of autonomy typically found within the working environment in Denmark (Hofstede *et al.,* 2010) resulted in an increased need from the engineers at the global R&D for clearly defined tasks and work packages. This increased the frequency of communications required when coordinating tasks, in particular at Company A, and resulted in frustration among the Danish engineers given the initial motivation for the collaboration was to free up their time and hence, allow them to work on more complex PD tasks. This is further highlighted in the following quotations: *"I think what we have experienced is the Indian engineers are very good if they get a very specific task with very clear limits or boundaries … they can do this, they do it very good…but often,*

you have to be very specified, you have to be very clear, you have to bring them very good templates to have a success." Danish mechanical engineer, Company A. *"The relief you have from moving tasks to India is pretty small, and since we've had very hard times defining our tasks and getting good results… most of what I see, most of our colleagues (at the Danish R&D)… they just basically do it themselves."* Danish mechanical engineer, Company A.

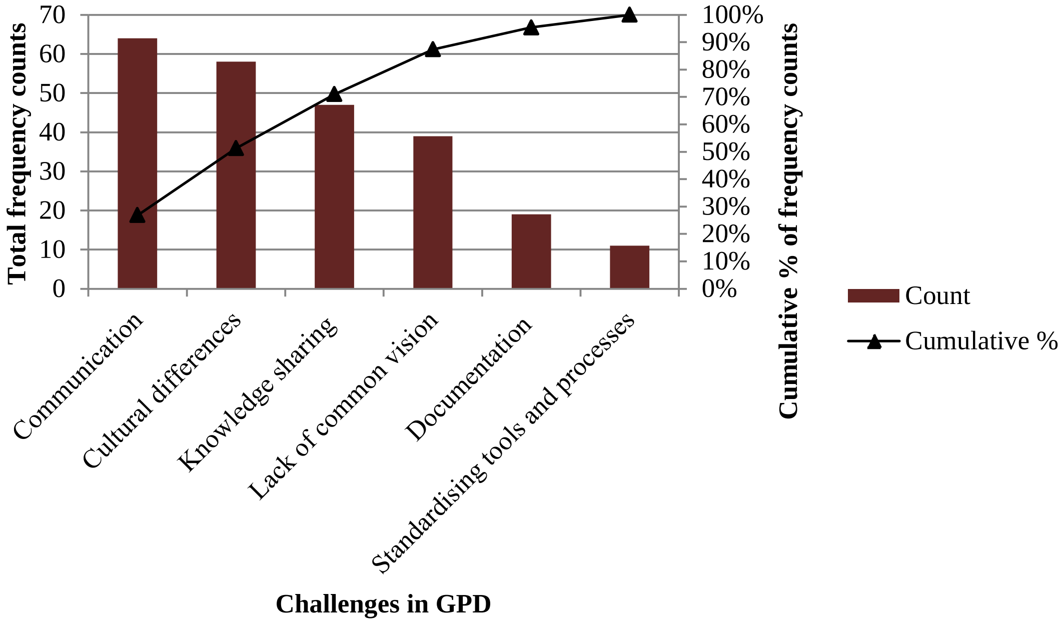

Figure 4 key challenges encountered during GPD at Company A

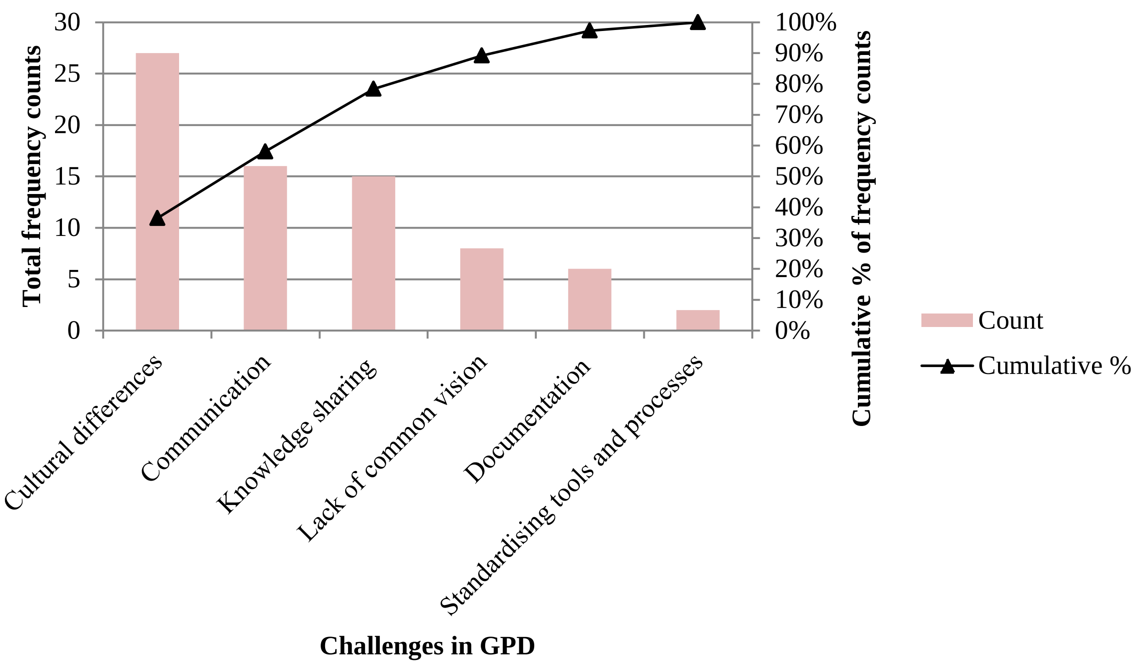

Figure 5 key challenges encountered during GPD at Company B

The availability of information for engineers was found to be a key moderator for the successful completion of local, cross-functional PD projects (Badke-Schaub and Frankenberger, 1999). However, GPD typically involves collaboration between geographically dispersed engineers and hence, the availability of information for global engineers to successfully complete PD tasks is often reduced. This results in an increased need for clearly defined tasks to enable culturally diverse engineers to work autonomously and is further supported in literature (Eppinger and Chitkara, 2009; Johnsen, 2011).

To improve collaborations at Company A and B, different management approaches were implemented during the observed GPD projects to reduce the risk of project failure (refer to section 3.1.1 and 3.2.2 for project backgrounds). These management approaches together with the key factors influencing success during the observed GPD projects are presented in the following sections. The insights primarily emerged from the observational studies as the time-causal relationship between the influence factors and their impact on the GPD projects could be observed.

4.2 Composition of global product development activities and the influence on project success

In Project I at Company A, the Danish project manager recommended following the digitalised PD process at the company (see Figure 2) with the intention to: (1) reduce negotiations between the Indian and Danish engineers regarding the prioritisation and sequence of tasks; (2) allow the distributed engineers to work concurrently and; (3) to support behavioural alignment within the project team. Each stage in the PD process consisted of standardised tasks to be completed before moving to the following stage, which is a typical approach for conducting PD projects in manufacturing companies (Figure 1). However, and despite recommendations from the Danish project manager to follow a single process during the project, the Indian engineers planned their activities according to a six sigma process they had recently received training in due to their lack of familiarity with the guidelines in the standard PD process at the company. This influenced the prioritisation of tasks within the project team during the early stages of the project and resulted in project time delays. For example, the Danish project manager spent considerable time during the concept development stage in re-aligning the tasks completed by the Indian engineers with those completed by the Danish engineers and hence, increased the workload for the Danish project manager.

At Company B, the stages in the standard PD process (Figure 3) were adopted during both Project II and Project III. In addition to the sequential stages in the PD process, the procedure was supplemented by techniques commonly found in agile PD; where the stages in the process were broken down into small and intense work streams named ‘Project sprints’ (Takeuchi and Nonaka, 1984), which typically lasted four weeks and with the aim of reducing PD time. Preceding the sprints, an extended project meeting was held at the Danish R&D facility including key project members with the aim of mapping tasks and activities to be completed for the next four week ‘Project sprint’. During these extended project planning meetings, the Polish engineers involved in

Project III were collocated at the Danish R&D facility and were heavily involved with the planning of tasks for the next four week 'Project sprint'. This involvement resulted in the creation of additional documentation for the collaboration to clarify: (1) the critical communication channels in the project and; (2) the understanding towards key project terminology across the global engineers, which reduced the dependency on the Danish project manager for such information and hence, reduced the workload of the project manager. However, given the increased distance between engineers in Project II, it was not possible to collocate the Danish and Chinese engineers during the project planning meetings. Rather, to support the alignment of tasks and enable the Chinese engineers to work autonomously during the project, PD tasks were decomposed according to the modules in the product to be developed. For example, each of the Chinese engineers was assigned to a product module that was best suited to their individual expertise, with a Danish engineer taking lead responsibility. However, on occasions this hindered project progress as the Chinese engineers were only knowledgeable about their specific module and relied on information from others regarding different product modules.

Clearly defining the interfaces between the planned tasks in the PD process and decomposing tasks into manageable work packages to be worked on autonomously is important when managing PD projects with globally distributed engineers to alleviate the coordination activities of the project manager. The colocation of the GPD project team to ensure key members are involved during important project planning session's further supports this (Figure 6).

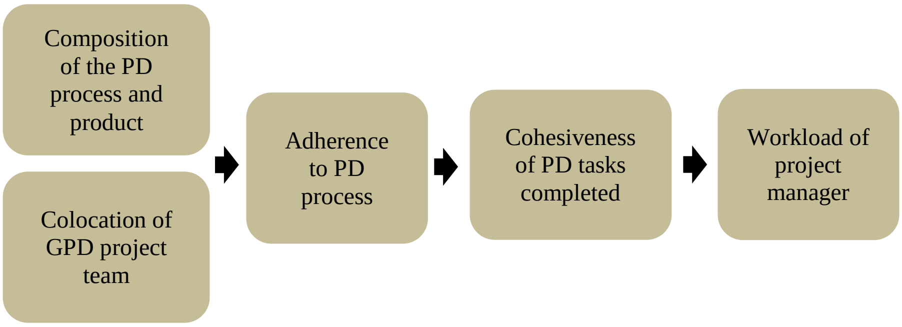

Figure 6 The cause-effect relatioships of the composition of PD activities on GPD project success

4.3 Level of project governance in global product development and the influence on project success

Project I at Company A was introduced to the Indian engineers as a 'Pilot' GPD project, where the solution was known by the Danish engineers from the outset to reduce the risk of project failure. The Danish engineers expected resource consumption to be kept low during the project with the intention of developing one or two high quality solutions to the problem in hand. Despite this and as a result of an in-depth root cause analysis conducted by the Indian engineers during the early planning stage of the project, a large number of complex solutions were proposed by the Indian engineers that would positively impact additional product variants at the company and hence, add value to the 'Pilot' project. The proposals were rejected by the Danish engineers as they were considered too ambitious, which created confusion among the Indian engineers in terms of the expectations and goals for the project. The extensive analysis and solution development by the Indian engineers resulted in design rework and delayed design approvals and was a key factor contributing to the project being delayed by two and a half months. Despite involving the Indian engineers from the early stages of the project, their input during the development of the product was restricted as the solution was already known by the Danish engineers to reduce the risk of project failure. As a result, the complexity of tasks and innovative freedom of the skilled Indian engineers was reduced and resulted in a misalignment of expectations and design rework.

At Company B, collocating globally dispersed engineering teams during PD projects, in particular during the early planning stages of GPD projects, was considered an important approach to ensure the alignment of interests within the globally dispersed project teams. However, in Project II, it was not possible to collocate the Chinese and Danish engineers and therefore, the Chinese engineers were introduced to the project during stage 3; where the main design of the product and key decisions regarding its development were already fixed. This routinised the development tasks for the skilled Chinese engineers and left little manoeuvrability for product design changes. At times, this resulted in design rework as when the Chinese engineers attempted to improve the main design of the product, they discovered that the Danish engineers had already attempted the same improvements unsuccessfully. Such scenarios were demotivating for the skilled Chinese engineers as despite the high complexity of the product to be developed; their freedom to develop was restricted. In contrast, it was possible to collocate the Polish and Danish engineers during the early stages of Project III at Company B and hence, the Polish engineers were heavily involved regarding the direction for design and development. The product to be developed in Project III was less complex than in Project I and II, however, the high involvement of the Polish engineers during the early project definition stage appeared to increase the level of commitment and project ownership among the Polish engineers.

In Project I and II, the level of project governance was increased to reduce the risk of project failure, which in turn reduced the complexity of tasks and innovative freedom of the skilled engineers at the global R&D facilities and led to a misalignment of interests and design rework (Figure 7). In Project III, collocating the Polish engineers and involving them in key decisions regarding the design of the product during the early planning stages of the project created a high level of project commitment, despite the low complexity of the product to be developed.

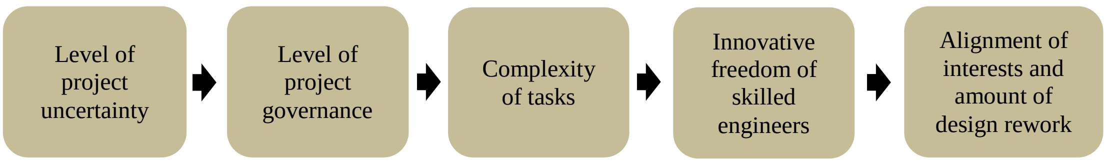

Figure 7 The cause-effect relationships of the level of project governance on GPD project success

In sum, difficulties in relation to communication and cultural differences during early collaborations with the global R&D at Company A and Company B resulted in adjustments towards the: *composition of the PD process and product* and *level of project governance* to reduce the risk of project failure in the observed GPD projects. Key factors influencing the success at the project-level included: *the complexity of tasks*; *the alignment of interests in the project team* and; *the workload of the project manager*.

4.4 Comparison of management approaches and influence factors in the observed global product development projects

To allow for comparison within and across the three GPD projects, the management approaches and the identified influence factors were rated (Table 7) and a meaningful interpretation of these results is presented and discussed in the following section.

		Project I	**Project II**	**Project III**
Management approaches	Level of project governance	4	4	3
	Decomposition of PD process	2	4	4
	Decomposition of product	n/a	2	n/a
Influence factors	Complexity of tasks	1	1	1
	Alignment of interests	1	3	4
	Workload of project management	4	4	2

Note: Rated from low (1) to high (4)

Table 7 Data matrix: Comparison of management approaches and influence factors across and within the investigated GPD projects

5. Discussion

Based on the findings in the previous section, three propositions were formulated. First, in Projects I and II where the level of governance was high, project uncertainty levels were lowered by reducing task complexity, which restricted the innovative freedom at the global R&D facilities. This can be explained given the difficulty in managing more complex tasks in GPD projects, where physical proximity is lacking and reducing task complexity has been described as an approach to avoid cultural misunderstandings and design rework (Hansen and Ahmed-Kristensen, 2011; Littler *et al.*, 1995). Furthermore, maintaining a high level of control at the parent company has been described as a strategy to counteract the accentuated challenges experienced with GPD projects, in particular for protecting the company's core competencies and dealing with a lack of trust towards competency levels in GPD teams (Eppinger and Chitkara, 2009; Hansen and Ahmed-Kristensen, 2011). However, in Projects I and II, the reduction in task complexity and the lack of freedom to develop for the global engineers resulted in a misalignment of interests in the project team and design rework as a number of more ambitious solution propositions were rejected. In comparison to local, cross-functional PD where cultural diversity is reduced and uncertain and ambiguous environments have been encouraged (Edmondson and Nembhard, 2009; Hoegl and Gemuenden, 2001), Project I and II indicate how the level of uncertainty is reduced in GPD projects to avoid cultural misunderstandings and design rework. However, providing skilled engineers, which are globally distributed, with sufficient responsibility towards development tasks while maintaining task stability is important and is further confirmed in literature (Eppinger and Chitkara, 2009; Kalyandurg and Akhilesh, 2012).

P1. In GPD projects where uncertainty is high, the level of governance is increased and task complexity is reduced to stabilise the environment and mitigate the risk of project failure. This restricts the innovative freedom in the project team and can lead to the misalignment of interests, design rework and project time delays.

The lack of clearly defined tasks in the PD process in Project I resulted in a lack of cohesiveness between tasks completed in the GPD team and hence, increased the workload towards coordination activities for the project manager. In Projects II and III, the tasks and activities were planned by the GPD team according to four week 'Project sprints', which encouraged the adherence to the PD process and played an important role in reducing the coordination activities for the project manager. A clear understanding towards the systematic approach for the development of products was found to be important in local, cross functional PD (Hales, 1987) and is further compounded in GPD given the need for the alignment of work packages in multiple geographic locations. In comparison to local, cross-functional PD, informal communications and interactions that support the alignment of interests within the team (McDermott, 1999) are restricted in GPD projects and the requirement for clearly defined, decomposed PD tasks and activities within the PD process is increased (Eppinger and Chitkara, 2009; Hansen and Ahmed-Kristensen, 2012).

P2. In GPD projects where informal communications are reduced, clearly defining the interfaces between planned tasks in the PD process and decomposing tasks into manageable work packages can support to alleviate the need for overt coordination activities for the project manager.

Similar to Project I and II, the level of governance was relatively high and the complexity of tasks was low in Project III. In contrast, the amount of time the Danish project manager spent coordinating tasks and activities appeared to be reduced and the alignment of interests within the team increased. The opportunity to collocate the Polish engineers and their high involvement during strategic planning sessions in Project III created a high level of project commitment and supported the alignment of interests within the project team. The early involvement of the Polish engineers in key decisions related to the development of the product in project III further supported this. These findings are confirmed in literature where the inclusion of geographically dispersed global partners during the early planning stages in GPD projects, has been described as an approach for avoiding the misalignment of interests during the later stages of GPD projects (Kleinsmann and Valkenburg, 2008; Littler *et al.,* 1995; McDonough *et al.,* 1999).

P3. In GPD projects, collocating globally dispersed engineers during the early planning stages supports the alignment of interests and can help in reducing the workload of the project manager towards the coordination and prioritisation of tasks.

5.1 Managerial and theoretical implications

The study builds knowledge regarding the global dispersion of engineering design activities in practice, which is seldom addressed with multiple longitudinal observational studies at the project-level in GPD, providing the basis for researchers and practitioners to develop practical tools in GPD. A strength of the current study is it adopts a multiple longitudinal case study approach, which is one of very few studies conducted in an industry setting that focus on real engineering design activities in a global context. To better manage the impacts on GPD projects, practitioners should:

- provide global partners with sufficient responsibility towards development tasks while maintaining task stability
- ensure the tasks in the PD process are clearly defined and decomposed into manageable work packages that can be worked on autonomously in multiple geographic locations
- collocate teams during critical stages in GPD projects, such as the early planning stage where key project decisions are made, to ensure project commitment.

6. Conclusion

The study contributes by building on the work of Eppinger and Chitkara (2009) and Hansen and Ahmed-Kristensen (2011) by investigating the way management approach PD with globally distributed engineering teams; and develops an in-depth understanding towards the time-causal effects that factors influencing success of GPD have at the project-level. Developing this understanding enables observed influence factors to be traced back to their initial causes and hence, informs management regarding the necessary precautionary strategies to be taken to better manage the impacts and support the transition from local, cross-functional PD to GPD.

In PD projects with globally distributed teams, issues related to cultural diversity and team proximity become increasingly significant in comparison to local, cross-functional PD and factors influencing the success at the project-level are accentuated (Anderson and Parker, 2012; Emden *et* *al.*, 2006; McDonough *et al.*, 2001). To effectively manage GPD, the decomposition of the PD process and adjustments to the level of project governance have been recommended in literature (Eppinger and Chitkara, 2009; Johnsen, 2011). However, the impact these management approaches have from the early planning through to the final testing and refinement stages of GPD projects is not well understood as the majority of studies in literature consist of interviews or observations of short design sessions, focussing on specific stages during the PD process (Hansen and Ahmed-Kristensen, 2011, Eris *et al.*, 2014). To investigate this, in-depth case studies were conducted with two large Danish manufacturing companies with a focus on engineering design activities in three GPD projects. A total of 21 semi-structured interviews, 43 hours of direct longitudinal observational studies and the analysis of project and company documentation were conducted, allowing for the triangulation of results and hence, strengthening the reliability and validity of the study.

Based on the findings, three propositions were developed that highlight how companies make adjustments towards the *composition of the PD process* and the *level of project governance* to reduce the risk of project failure in GPD projects. Key factors influencing the success at the project-level included: *the complexity of tasks; the alignment of interests in the project team* and; *the workload of the project manager* and resulted in project time delays and design rework. Tracing observed influence factors back to their initial causes supports to inform management regarding the necessary precautionary strategies to be taken to better manage the impacts in GPD. For example, based on the findings management should: provide global partners with sufficient responsibility towards development tasks while maintaining task stability; ensure the tasks in the PD process are clearly defined and decomposed into manageable work packages that can be worked on autonomously in multiple geographic locations, and; collocate teams during critical stages in GPD projects, such as the early planning stage where key project decisions are made, to ensure project commitment.

Overall, the study builds knowledge regarding the global dispersion of engineering design activities in practice, which is seldom addressed with multiple longitudinal case studies, providing the basis for researchers and practitioners to develop practical tools in GPD. A strength of the current study is it adopts a multiple longitudinal case study approach, which is one of very few studies conducted in an industry setting that focus on real engineering design activities in a global context. A limitation, however, is that single factors such as culture or distance cannot be blocked as in experimental studies. Despite this, the benefits of our approach outweigh the limitations considering the aims of the research study. However, caution should be taken when generalising the findings reported. The results of the empirical studies are derived from the analysis of large Danish manufacturing companies who currently offshore parts of their PD process and hence, it makes sense to state that the findings are valid within this context. There is a requirement for additional longitudinal observational studies that trace observed problems in GPD back to their initial causes and hence, provide indication as to where precautionary strategies should be developed to further support the management of GPD projects.

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Appendix 5.7 Paper VII

Reference: Taylor, T. P. and Ahmed-Kristensen, S. (2016), “Global product development: KPI selection support” 14th International Design Conference – DESIGN, 2016, Dubrovnik, Croatia.

Authors	Taylor, T. P., Ahmed-Kristensen, S.
Title	Global product development: KPI selection support
Submitted to	14th International Design Conference, DESIGN 2016, Dubrovnik, Croatia. (To be extended to a journal paper once additional test companies are identified).
Research aim	Current methods that adopt a goal-oriented approach to measuring performance in conventional PD do not provide sufficient support to monitor the challenges that influence GPD success along the process. There is a need to validate the method of support developed, which aims to provide project managers with support for selecting lagging KPIs - that measure the outcome of the process, and leading KPIs - that monitor the factors influencing the process, in GPD at the project-level.
Research stage	Design Research Methodology: Prescriptive study → Descriptive study II
Research approach	2 longitudinal case studies (Company A and B) and a third company case study were conducted to develop, test and evaluate the method of support developed that supports the selection of KPIs.
Summary of findings	The approaches adopted for selecting KPIs did not provide sufficient structure to select and document leading KPIs that monitored the challenges in the GPD projects. There is a requirement to balance lagging KPIs with leading KPIs to provide accurate and timely feedback to support (and if necessary adjust) decisions along the process. A method of support was developed to support project managers for selecting both leading and lagging KPIs at a project-level in GPD. Initial results from testing and participant evaluation at a third company case study indicate the method of support guided with the selection of leading KPIs, which resulted in preventative actions being implemented at the company. In addition, identifying and prioritising critical factors influencing success, prior to the selection of the KPIs, proved a valuable element of the support method and supported in aligning the interests of different parties involved in the project. Further testing is required to validate the method of support in the context of GPD.

Contribution	The paper contributes to the thesis by introducing a shift from traditional goal-oriented approaches to selecting KPIs by developing and testing a challenge-oriented approach, which focuses on selecting leading KPIs that minimise the risk of factors influencing success along the process. The selection of leading KPIs resulted in preventative actions being implemented to avoid the challenge of a lack of common vision across functions.

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GLOBAL PRODUCT DEVELOPMENT: KPI SELECTION SUPPORT

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Keywords: [this will be inserted automatically]

1. Introduction

The migration from collocated, cross-functional product development (PD) to a form of Globally Distributed PD (GPD) represents a major transformation in industry. This is particularly evident when managing PD projects with globally distributed teams, as cultural diversity and team proximity accentuate difficulties traditionally found in conventional PD projects [Anderson and Parker 2012, Hansen and Ahmed-Kristensen 2011]. To effectively manage GPD projects, the selection of Key Performance Indicators (KPIs) is recommended, which enable the discovery of deviations early on and support managers to resolve problems when they arise [Christodoulou et al 2007, Hansen and Ahmed-Kristensen 2012]. The selection of KPIs has been investigated in the operations management field from a business process perspective [Kaplan and Norton 1996, Neely et al 2000]. However, research on KPIs in the field of engineering design is relatively sparse, particularly when tasks and activities are globalised.

In this paper, we develop an understanding toward the selection and use of KPIs in GPD projects informed from the findings of two in depth case studies conducted with large Danish manufacturing companies. Based on the findings a framework was developed, which provides a process to: address the selection of KPIs specifically for GPD; support the selection of both Leading and Lagging KPIs and; minimise the impacts as a result of the challenges in GPD in addition to KPIs selected that are goal-oriented. The framework was tested and evaluated in a third company and initial results indicate the framework supported the selection of Leading and Lagging KPIs, which resulted in preventative actions being implemented at the company. Furthermore, the framework supported in aligning the interests of cross-functional team members involved in the project.

2. Literature review

The literature reviewed draws on two fields, namely; the globalisation of tasks and activities in the field of engineering design and the selection of KPIs in the operations management field.

2.1 Global Product Development

Many Western companies have begun to globalise parts of PD, the first being manufacturing activities with design activities following. GPD is the globalisation of tasks and activities throughout the PD process, from the early concept development phase and detail design through to the final testing of prototypes. The decision to globalise parts of PD is a consequence of an increasingly competitive world market as companies look to reduce development costs, access new resources and get closer to their global market. However, difficulties of coordinating tasks and activities in GPD projects in comparison to conventional PD have been highlighted as cultural diversity and team proximity accentuate factors influencing success [Anderson and Parker 2012]. Table 1 highlights key challenges and motivations observed in GPD from case studies conducted in the manufacturing industry. Companies often pursue GPD to reduce costs by utilising low labour costs in regions such as India and China. However, recent work found that companies pursue GPD for other reasons than those directly related to cost reductions [Eppinger et al 2009] and less tangible benefits, such as increasing access to new technologies or improving flexibility in operations become significant. Previous studies indicate that companies adopt a learn-by-doing approach to GPD when dealing with challenges, such as those in Table 1, with solutions to managing the impacts on PD implemented on an ad-hoc basis. This can be costly further down the PD process. For example, studies by Hansen and Ahmed-Kristensen [2011] discovered that companies only considered positive impacts of moving abroad, leaving few processes in place to handle the difficulties. Solutions to these difficulties were implemented on an 'as-needed' basis and at times resulted in design rework and project time delays. Barthelemy [2003] highlights the need to understand the hidden costs as these impact the success of GPD and challenge the decision rationale. To better manage these difficulties there is a requirement for practical frameworks that support management when making decisions in GPD projects [Eppinger and Chitkara 2009]. More specifically, selecting KPIs in GPD that provide managers with continuous feedback along the process is recommended to allow deviations to be discovered early on [Hansen and Ahmed-Kristensen 2012].

Table 1 Key challenges and motivations in GPD

Key challenges [Hansen and Ahmed-Kristensen 2012]	Key motivations [Christodoulou et al 2007]
Cultural differences	Access to new resources
Lack of common vision	Increase customer base
Documentation	Cost reductions
Alignment of interfaces	Reduce time to market
IP rights and security	Risk mitigation
Knowledge sharing	Flexibility & Scalability
Standardising tools & processes	

2.2 The selection of Key Performance Indicators

In comparison to manufacturing or conventional PD, performance measurement in GPD is relatively unexplored [Taylor and Ahmed-Kristensen 2014]. However, the operations management field provides a theoretical basis to investigate the selection and use of KPIs. In this context, KPIs are defined as quantifiable metrics that help measure the success of identified critical factors. Kaplan and Norton [1996] classify KPIs within two categories:

- Leading KPIs: that measure factors impacting a process and are drivers of performance.
- Lagging KPIs: that measure output of past activity and typically consist of financial indicators.

The selection of Leading and Lagging KPIs must be balanced. Lagging KPIs (outcome measures) without Leading KPIs (performance drivers) do not communicate how the outcomes of a process are to be achieved. Leading KPIs focus on monitoring the factors influencing success of a process and can inform management of where to make adjustments along the process. However, a general criticism of KPIs in PD is they are Lagging and provide a time-delayed retrospective look on performance, rather than an instantaneous evaluation or predictive insight required to make adjustments along the process [Tatikonda 2007]. Neely et al [2000] propose six criteria for selecting KPIs. These are: (1) KPIs should be derived from company strategy, (2) The purpose of the KPI must be made explicitt, (3) Data collection and methods of calculating performance must be clear, (4) All stakeholders must be involved in the selection of the KPIs, (5) The KPIs should take account of the organisation and (6) the KPIs should change as circumstances change. In project management literature for PD there is agreement that KPIs should be selected according to key performance dimensions: Development Time, Cost and Product Quality [Hoegl et al 2004]. Additional frameworks to support the selection of KPIs include work by Neely et al [2000] on performance measurement system design and the

Balanced Scorecard by Kaplan and Norton [1996]. However, the two frameworks support the selection of KPIs at a business-level and provide little support for selecting KPIs at a project-level in the context of GPD.

In sum, there is a lack of research that focuses on the selection and use of KPIs in GPD projects. Selecting Lagging KPIs alone provides a time-delayed, retrospective look on performance. In GPD projects where factors influencing success are accentuated, there is a requirement to monitor these to inform management of when to make adjustments along the process and hence, encourage the selection of leading KPIs. Based on this review, the research aim and approach is described in the following section.

3. Methodology

3.1 Research aim and approach

The aim of the research was twofold: first to develop an understanding towards the selection and use of KPIs in GPD projects and second; to develop and test a framework that provides a structured approach for selecting and reporting KPIs in GPD at a project level. Two in depth case studies with large Danish manufacturing companies were conducted with a focus on two GPD projects. These provided the necessary understanding of real time tasks and activities to address the first aim [Voss et al 2002]. For the second aim, the results from a third company case, where the framework was tested, are presented and described in Section 5: Framework development.

3.2 Description of case studies

Company A and B represent two large Danish manufacturing companies with recently established global R&D sites in India and China (see Table 2 for company and project characteristics). A high involvement of the global R&D sites with engineering design activities was a key criterion for selection to allow for comprehensive investigations of GPD projects.

3.2.1 Company A: Project I

The company specialises in the production of industrial valves and controls for the refrigeration and air conditioning markets. In 2011, the company established an offshore R&D department in India with the key motivation to reduce costs by gaining access to low labour costs of skilled engineers in India. However, the Danish engineers experienced difficulties with the Indian engineers and a number of tasks and activities were neither completed on time nor to the desired quality. The motivation of the Indian engineers towards the tasks, which were routine in nature, was seen as a contributing factor to these difficulties and therefore, a lead engineer in Denmark involved the Indian engineers as the "main drivers" in a more complex PD project, referred to here as Project I. The project involved 10 experienced mechanical engineers from India and Denmark and forms the basis for the results reported in this paper for Company A. The objective was to improve the performance of an existing valve range by increasing the product lifetime. The project was introduced as a "Pilot" project and the solution was known by the Danish engineers with the primary aim to improve the collaborations, whilst keeping risk low. The project followed the company’s standard PD process for PD projects (Figure 1).

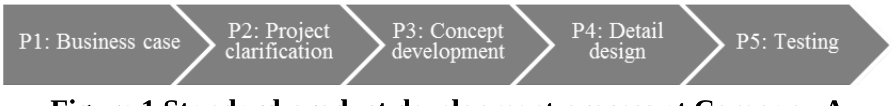

Figure 1 Standard product development process at Company A

3.2.2 Company B: Project II

The company specialises in the development and manufacture of blood analysis instruments, such as blood gas analysers and syringes for the pharmaceutical industry. The company had recently established an offshore R&D department in China with the key motivation to reduce costs by gaining access to skilled engineers in low cost regions. From the beginning of the collaboration, the Chinese R&D were introduced to Project II in the Product and process design phase at the company (see Figure

2 for PD process followed). The project involved 14 mechanical engineers from China and Denmark and forms the basis for the results reported in this paper for Company B. The aim of Project II was to develop a new blood gas analyser that performed at a higher speed than those currently on the market. The product to be developed was complex, including 15 different modules, with the project team organised according to these modules to allow for the global segregation of design tasks.

Figure 2 Standard product development process at Company B

Table 2 Characteristics of Company A (Project I) and Company B (Project II)

Characteristics of companies	Company A (Project I)	Company B (Project II)
Industry sector:	Refrigeration & air conditioning	Pharmaceutical
Product to be developed in project:	Industrial valve	Blood gas analyser
Expected duration of PD project (before production):	4 months	4 years
Offshored R&D site involved in project:	India	China
Years offshored R&D established at time of study:	2.5	1.5

3.3 Data collection and analysis

The empirical results presented in the following section are based on 43 hours of direct, longitudinal observational studies, 21 semi-structured interviews and the analysis of company documentation (Table 3); allowing for triangulation of the results, which strengthened the reliability and validity of the findings. The observations took place during key project meetings over a period of eight months at Company A, from Business case to Testing (Figure 1), and three months at Company B, during Product and process design (Figure 2). The researchers did not actively participate during these observations. Field notes were taken, which were structured according to the research aims of this paper and transferred into a coding scheme for further analysis. Despite the observation of fewer phases in Project II than Project I at Company B, interviews and document analysis enabled the projects to be investigated retrospectively. The semi-structured interviews lasted ca. 60 minutes, with interviewees selected based on their involvement in the GPD projects under investigation. The questions related to: the motivations and challenges in the GPD projects; the impact of these on PD and; the KPIs used for monitoring performance. The interviews were audio recorded, transcribed and transferred into a predefined coding scheme for further analysis. The coding scheme was developed based on the literature review where possible. However, given the relatively sparse research on the selection of KPIs in GPD projects, codes were also generated from the empirical studies to avoid the confinement of data and added to the predefined coding scheme. The coding scheme consisted of three main elements: The challenges and motivations in GPD, the impacts on GPD projects and the KPIs selected according to Leading and Lagging. The KPIs were classified within the performance dimensions Development Time, Cost and Product Quality. KPIs that could not be classified were placed in an "Other" category. The analysis of code co-occurrence indicated key patterns within the data and provided an understanding of the rationale and theory underlying relationships. Documentation related to detailed project plans, risk assessments and key project metrics were collected and analysed qualitatively.

Table 3 Characteristics of data collection methods

Characterisitics of data collection	Company A	Company B
Interviewees' positions:	Senior Mgt., Program Mgt., Mechanical engineers	Senior Mgt., Program Mgt., Mechanical engineers
Nr. of interviews:	11 interviewees	8 interviewees

Hrs. of observations:	26	17
Analysis of documents	Project plans, Risk assessments, Project metrics, meeting minutes	Project plans, Risk assessments, Project metrics, meeting minutes

4. Findings

The empirical observations presented in this section in Company A and B were made without intervention and address the first aim of this paper. The process for selecting KPIs in Project I and II is described here and the resulting KPIs are presented. The key challenges encountered in the projects are further exemplified.

4.1 KPI selection process

In Project I, a structured approach for selecting KPIs was not followed; rather the KPIs selected at a project-level were largely based on the experience of the project manager. However, the tasks undertaken in the Business case phase at Company A assisted the project manager in setting budgetary requirements, project schedules and predefined product quality requirements for the project, which were aligned with high-level KPIs at the company. Similarly, project-level KPIs were to adhere with high-level KPIs in Company B such as: Project schedule and Costs, Customer satisfaction and Product quality. To further support the selection of project-level KPIs, a KPI selection workshop was held in the Project initiation phase of Project II, with the high-level KPIs as the starting point. The primary approach for selecting KPIs during the workshop was a brainstorming session within the project team where members were asked to select KPIs they would like to work with in Project II, whilst adhering to the high-level KPIs at the company. However, there was a lack of experience and understanding of the purpose within the project team toward selecting and using KPIs and the project manager experienced difficulties with gaining commitment. Only a few members of the team actively participated in the brainstorming session. The limitations of such approaches when selecting KPIs have been highlighted in literature [Barr 2014]. Furthermore, the importance of including all project members when selecting KPIs is a key characteristic when designing KPIs [Neely et al 2000]. Such involvement enables KPIs to be selected according to the interests of stakeholders, which is important for gaining commitment. Despite this, the global R&D was not involved in the selection process.

4.2 KPIs in the GPD projects

Table 4 presents KPIs selected in Project I and II according to performance dimensions typically found in project management: Development Time, Cost and Product Quality. It was possible to classify the majority of the selected KPIs according to these dimensions, with the exception of four "Other" KPIs, which could not be directly classified. This can largely be explained given the adherence to the high-level KPIs during the selection of project-level KPIs in both projects, which related to project costs, time schedules and product quality objectives. Many of the KPIs selected relate to Development Cost and represent financial KPIs (Lagging KPIs), which have been described as measuring the output of past activity, rather than monitoring the impacts on a process (Leading KPIs) [Kaplan and Norton 1996]. Considering the primary motivation for the collaborations in both projects was to reduce costs, these financial KPIs can be expected. Furthermore, selecting financial KPIs is common as these are more tangible and easy to measure. These findings demonstrate that KPIs related to performance dimensions in project management are also important when evaluating the success of GPD projects. However, these have been described as providing a time-delayed retrospective look on performance [Tatikonda 2007] and are Lagging in nature, rather than instantaneous measurement or predictive insight required to avoid the challenges in GPD i.e. Leading in nature. The four "Other" KPIs in Table 4, which could not directly be classified according to performance dimensions in project management, were important in the projects and were a result of identified project challenges related to: a lack of common vision in the teams and poor documentation. However, on occasions, the "Other" KPIs were used as Lagging KPIs and provided time delayed information towards the impacts on the projects. For example, despite a lack of common vision being identified in the Project clarification phase of Project I as a factor impacting project success; a KPI was not selected to monitor this during the KPI selection process. Rather, the KPI Internal design expert feedback was used after a lack of common vision had occurred in the Detail design phase, providing time delayed information toward the challenge. This is further exemplified in the following section. In Project II, it was identified during the KPI selection workshop that the time taken for project documents to be approved internally was a challenge that could result in project time delays. Given adherence to project schedule was an important high-level KPI for the project, the KPI Documentation approval time was selected as a Leading KPI in the project to monitor this and make adjustments along the process if approval time was to be delayed. Furthermore factors impacting the success of the Lagging KPIs, such as Project lead time, were identified and activities were set up to prevent missed deadlines. Although the "Other" KPIs in Table 4 do not directly measure Development Time, Cost and Product Quality; they monitor factors impacting the success of these dimensions, such as a lack of common vision and documentation issues, and identifying such challenges early in GPD projects and selecting and documenting KPIs that monitor them is important to avoid the impacts.

Table 4 Selected KPIs and definitions according to performance dimensions in Project I and II

Performance dimensions in PD projects	Key Performance Indicator selected in GPD projects	Definition	Project I	Project II
Development Cost	Cost of Product Development	Estimated resources required for product development	x	x
	Return on investment	Yearly cost savings after investment	x	x
	Planned Vs Actual resources	Expected resources used in comparison with actual used	x	
	Total project cost	Estimated reources required for product development		x
	Cost of delay	Financial implications of project delays		x
Development Time	Project lead time	Amount of time from project initiation to completion	x	x
Product Quality	No. of product lifecycles	Durability of the product	x	
	Customer satisfaction	Usability of product prototypes	x	x
Other	Documentation errors	Number of errors found in drawings completed by global R&D	x	
	Documentation approval time	Time taken to approve documents by internal approval board		x
	Internal design expert feedback	Feedback from design experts at company, external from project	x	
	Supplier feedback on assembly	Feedback from supplier early in product design phases of project	x	x

4.3 A lack of common vision in the GPD projects

A lack of common vision within the team was a key challenge encountered in the GPD projects, which resulted in design rework and project time delays. As stated earlier, Project I was introduced to the Indian engineers as a "Pilot" project with the aim of improving collaborations. As such, the Indian engineers invested a large amount of time and resources in the early phases of the project and proposed a number of solutions, which would potentially add value to Project I and impact additional product variants outside of the project. These propositions were rejected in the Detail design phase of the project when using the KPI: Internal design expert feedback, as they did not fit within the scope of the solution the Danish engineers had in mind. This resulted in confusion amongst the Indian engineers in relation to the project expectations and caused design rework and contributed to the project being delayed by two and a half months. A lack of common vision within the team was identified as a factor impacting project success when conducting the project risk assessment in the

Project clarification phase of Project I. However, the KPI: Internal design expert feedback was used late in the process as a Lagging KPI and provided time-delayed information in relation to the lack of common vision. Hence, the KPI did not provide the predictive insight required in order for necessary intervention action to avoid project time delays. A Leading KPI, described as KPIs that monitor factors impacting a process [Kaplan & Norton 1996], was not selected to monitor the lack of common vision. In Project II, a lack of common vision was encountered during the design development phase, which resulted in design rework. In Project II, key decisions regarding the design for the gas analyser were already made when the Chinese engineers were introduced and the main design was fixed. This routinised the development tasks and reduced project uncertainty, leaving little manoeuvrability for design changes by the Chinese engineers. However, early in the collaborations, the Chinese R&D expressed their willingness to work on complex development tasks. This resulted in design re-work as when the Chinese engineers attempted to improve their individual product modules, they discovered that the Danish engineers had already attempted the same improvements unsuccessfully. Such scenario was demotivating for the Chinese engineers as innovative freedom was reduced. The lack of common vision in the project was not highlighted as a key challenge during the KPI workshop and a Leading KPI was not selected to monitor this to allow the avoidance of design rework. Involving the global R&D during the KPI workshop may have highlighted this challenge at an early phase with the importance of involving all stakeholders in the selection process highlighted in literature [Neely et al 2000]. A lack of common vision is also a common challenge in conventional PD, however similar studies describe how team proximity and cultural differences accentuate this [Anderson and Parker 2012, Hansen and Ahmed-Kristensen 2011] and the impacts on GPD projects require monitoring.
Considering the first aim of this paper, an understanding has been developed in relation to the selection and use of KPIs in GPD projects. To summarise, the approach adopted for selecting KPIs did not provide sufficient structure to select and document Leading KPIs that monitored the challenges in the GPD projects. KPIs selected according to Development Time, Cost and Product Quality are important for GPD projects. However, there is a requirement to balance these with Leading KPIs, which monitor the factors impacting success toward the performance dimensions (such as the challenge factors in Table 1). This will provide accurate and timely feedback to support (and if necessary adjust) decisions along the process.

5. Framework development

This section describes the development of a framework that supports the selection of Leading and Lagging KPIs in GPD projects, which was developed based on the findings in the previous section. Initial testing and evaluation of the framework is described with a third company case.

5.1 The KPI Toolkit: Support for the selection of KPIs in GPD projects

Building on previous work in the field of GPD [Hansen and Ahmed-Kristensen 2012] and operations management [Kaplan and Norton 1996, Neely et al 2000], the KPI Toolkit aims to support project managers for selecting both Leading and Lagging KPIs at a project-level in GPD. Including a challenge-oriented approach to selection, the KPI Toolkit provides an alternative basis to design, select and document KPIs than those described in literature, encouraging the selection of Leading KPIs to monitor the factors impacting GPD projects. There are three phases to the KPI Toolkit, which support practitioners to prepare, stage and execute a KPI selection workshop:

- Phase 1 (Project team): Develops an understanding towards key concepts for selecting KPIs, e.g. the purpose and value of KPIs, the relationship between Leading and Lagging KPIs.
- Phase 2 (Project team): Provides a structured approach for selecting project-level KPIs according to critical impact factors in GPD.
- Phase 3 (Project Mgt.): Provides templates for the documentation of the selected KPIs.

Before using the KPI Toolkit, the experience with selecting and using KPIs in the project team and maturity of the GPD project are assessed to determine the starting phase in the toolkit, e.g. if key concepts for selecting KPIs are understood then Phase 1 can be skipped. Phase 1 and 2 require participation from key members of the project team and Phase 3 can be completed by the project manager alone. The time required to complete all three phases is ca. 5 hours with the majority of time allocated for Phase 2: KPI selection. The core elements to Phase 2 are illustrated in Figure 3. The framework highlights three levels of performance measurement: the business-unit level, the project-level and the task-level and KPIs selected at each level must be coherent. In this paper we focus on KPI selection at the project-level. The following key steps are conducted in Phase 2:

- First, key motivations and challenges for the GPD project are selected (according to those in Table 1), prioritised and mapped to a cause-effect Fishbone diagram [Ishikawa 1990]. The Fishbone diagram is used to identify possible factors impacting the success of a specific event or desired outcome and has been adopted by researchers attempting to understand the effects of outsourcing in general [Kitcher et al 2013]. Strategies to prevent the impacts as a result of the challenges and achieve the motivations are then planned and prioritised. Leading KPIs are designed for monitoring the activities as a result of the selected challenges and their impacts on success, and Lagging KPIs to evaluate performance towards the selected motivations.
- Second, the activities are mapped to the company PD process with indication of where along the process the selected KPIs require monitoring.
- Third, the selected KPIs are reported in a KPI template, which includes information related to the Purpose of the KPI, the challenge or motivation it relates to, the main responsible for the KPI and the frequency of measurement and targets.

Phase two of the KPI Toolkit is reviewed at important project intervals, such as after key milestones in the PD process to ensure the KPIs change as project circumstances change.

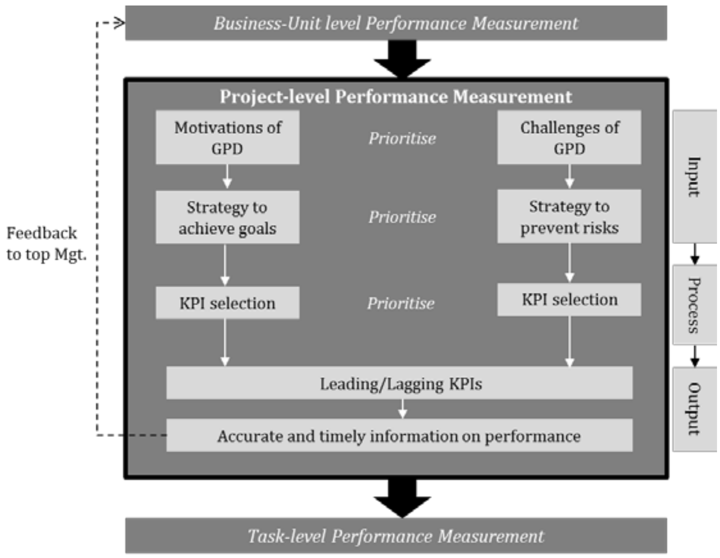

Figure 3 Framework to support the selection of Leading and Lagging KPIs in GPD projects

5.2 Testing

The KPI Toolkit was tested in a large Danish manufacturing company that specialises in the production of ventilation and air handling systems in the marine and offshore sector. It was not possible to test the toolkit in a GPD project; however, the company were interested in testing the toolkit to set up KPIs in a software development project, which aimed to develop a common platform for conducting and documenting future PD projects at the company. Despite being a software development project, the project was expected to follow the standard PD process employed at the company from the early planning and conceptualisation through to the final testing and evaluation of the software. Six core members of the project from the mechanical engineering department participated in testing the KPI Toolkit, including general and top level management. When assessing the experience with selecting and using KPIs, the project team decided that all three phases of the KPI Toolkit were required. The workshop lasted ca. 4 hours and was conducted during the early planning phase of the project. As a result of the workshop, key motivations selected and prioritised for the project were to: Reduce PD costs and Reduce time to market. The critical challenge factors impacting the success of these were selected, prioritised and identified as: a lack of common vision across functions at the company and communication problems within the project team. For the lack of common vision, plans were made to create a document where the level of acceptance in relation to the software being developed would be measured across functions. Two Leading KPIs were documented in the KPI template for monitoring the challenge factors impacting success, namely: The level of participation of key project members during project meetings and Alignment of interests across functions during the project, which were related to the Lagging KPIs: Product development cost and Product development time respectively. The key steps followed during phase 2 were documented in the templates developed to allow for the learnings to be passed to future projects at the company.

5.3 Evaluation

The focus for the evaluation was on the process for selecting KPIs in the KPI Toolkit and included a survey with five participants, before and after the workshop. This was supplemented with interviews with two of the participants five months after the workshop to allow time for implementation. The evaluation was conducted following Kirkpatrick's approach extended by Ahmed-Kristensen [2001]:

1. Reaction: The usefulness and applicability of the KPI Toolkit.
2. Learning: The increased understanding of the key concepts for the selection of KPIs.
3. Results: The difference between KPIs selected before and after the KPI Toolkit.
4. Validation: The improvements required to support the selection of KPIs.
5. Behaviour: The impact the KPI Toolkit had on everyday tasks and activities.

The survey focussed on the first four evaluation principles outlined above. Results were positive with mutual agreement from the participants that the KPI Toolkit supported the selection of Leading and Lagging KPIs, which were not in place prior to the workshop. Strategies were planned in order to prevent identified factors impacting project success with Leading KPIs selected to monitor these. To evaluate the impact on behaviour, interviews were conducted five months after the KPI Toolkit was tested. During the interviews, it was discovered that the start date for the project had been delayed and the selected KPIs had not yet been implemented. However, the planned strategies as a result of the workshop were underway with the KPIs expected to be implemented. Furthermore, the interviewees found that adopting the Fishbone diagram to identify critical factors impacting the success of the project supported in aligning the common vision within the project team, which is often a challenge experienced in non-collocated projects. In addition, by highlighting the impact factors that supported the formulation of the KPIs, the interviewees felt this increased the likelihood of team members accepting and using the KPIs. The knowledge gained during phase 2 of the KPI Toolkit, in particular the increased understanding of Leading and Lagging KPIs, had been used indirectly within the company and passed on to other projects. In their evaluation of the KPI Toolkit an interviewee stated:
"We have used the mind-set of not only measuring the end result but also how to improve the process as we go along… it really has impacted a lot on the way we approach and discuss KPIs, and also the structured way to identify and categorise has been very helpful", Project manager.

7. Conclusion

Research toward the selection and use of KPIs in engineering design, in particular when parts are globally distributed, is sparse. Two in-depth case studies with large Danish manufacturing companies with global R&D functions in India and China addressed this. The main findings highlighted the use of Lagging KPIs in the observed GPD projects, which were selected according to traditional performance dimensions found in conventional PD, namely: Development Time, Cost and Product Quality. However, the Lagging KPIs did not provide the predictive insight required to avoid challenges related to a lack of common vision, resulting in project time delays and design rework. Performance dimensions in conventional PD support a goal-oriented approach to selecting KPIs, which are Lagging in nature, and typically influenced by top-down company strategy. However, the GPD projects highlight the need for a challenge-oriented approach to selecting KPIs, i.e. in order to identify the challenge early in the process and minimise the impact of a lack of common vision on GPD project success. Based on these findings and building on previous work in the fields of operations management [Kaplan and Norton 1996, Neely et al 2000] and engineering design [Hansen and Ahmed-Kristensen 2012], a framework was presented and evaluated, which provides a process to: address the selection of KPIs specifically for GPD; support the selection of both Leading and Lagging KPIs and; minimise the impacts as a result of the challenges in GPD in addition to KPIs selected that are goal-oriented. The framework was tested with a third company case and initial results indicate the framework supported the selection of Leading KPIs, which resulted in preventative actions being implemented at the company. Furthermore, identifying critical factors impacting the success prior to the selection of the KPIs proved a valuable element of the framework and supported in aligning the interests of different parties involved in the project. It was not possible to test the framework in a GPD project, which is a limitation of the study. Future studies will focus on testing the framework in the context of GPD for further validation. The results of the empirical studies are derived from the analysis of Danish manufacturing companies who globalise PD and hence, the findings are valid in this context. Building on previous research in GPD and adapting key aspects from operations management, this paper has: developed an understanding of how KPIs are selected and used in GPD projects and; developed and tested a framework, which provides an alternative approach to design, select and document KPIs in GPD than those found in literature by incorporating a challenge-oriented approach to selection. The study builds knowledge regarding the global dispersion of engineering design activities in practice, which is seldom addressed with multiple longitudinal observational studies, providing the basis for researchers and practitioners to develop practical tools in GPD.

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